IMPINGEMENT AND ENTRAINMENT STUDIES

FOR

NORTH ANNA POWER STATION

1978 - 1983

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EXECUTIVE SUMMARY

The following report summarizes and analyzes impingement and entrainment data collected from the cooling water intake structure (CWIS) of Virginia Power's North Anna Power Station located on Lake Anna, in Louisa County, Virginia. Included are data collected weekly from early 1978 through 1983. In addition to impingement and entrainment data, the report includes a description of the site, station and operating history. Analyses of the data appear to demonstrate from a holistic approach that the biological impact of impingement and entrainment is having a minimal impact on the ecosystem of Lake Anna.

In 1972, Virginia Power impounded the North Anna River creating Lake Anna, resulting in a 3885 hectare (9600 acres) reservoir that provides condensor cooling water for its North Anna Power Station and a 1376 hectare (3400 acre) Waste Heat Treatment Facility that receives the cooling water and transfers the heat from the water to the atmosphere before discharge into the reservoir. Lake Anna is 27 km (17 miles) long with over 438 km (272 miles) of shoreline and is located in Louisa, Spotsylvania and Orange Counties within the Piedmont province of Virginia. Normal lake elevation is 76.2 m (250 feet) above sea level and the mean depth is approximately 8m. From its inception, Lake Anna was designed as a multipurpose facility to accommodate both the power station and recreational users. When flooded, the rolling terrain of the North Anna River valley created a dendritic lake with countless coves and fingers. Shoreline development of permanent and vacation homes soon followed, along with development of several marinas and campgrounds. A state park is under development using Lake Anna as its keystone. Abandoned roadbeds were left

intact to serve, where accessible, as paved boat ramps. Clearcutting the lake bottom prior to filling has resulted in acres of water safe for skiers, power boaters and sailboaters. The Virginia Commission of Game and Inland Fisheries recognized Lake Anna's multiple use potential and began a management plan by stocking several species of fish. The result to date has been the creation of a lake with ever-increasing popularity for sport-fishermen.

The North Anna Power Station consists of two nuclear units with a total design rating of 2,910 Mwt. Commercial operation for Unit 1 began in June 1978; Unit 2 became commercial in December 1980. Eight circulating water pumps (4 pumps/Unit), each rated at 13.9 m^3/s, are located at the intake structure. The once-through cooling water system is filtered by a single rotating traveling screen (9.5 mm mesh) in front of each pump. The nominal temperature change across the condensors is 7.8°C.

Impingement estimates, representing 34 species, ranged from 4.6×10^4 in 1979 to 5.8×10^5 in 1983. Entrainment estimates within five dominant species ranged from a total of 8.4×10^7 fish larvae in 1982 to 2.5×10^8 in 1981. As supported in text discussions, these numbers are considered too low to have a significant biological impact on Lake Anna. No fish eggs were entrained during the study as all reproducing fish species in Lake Anna are nest builders and/or have adhesive eggs. Gizzard shad, yellow perch, black crappie, bluegill and white perch were the most commonly impinged and entrained fishes. Gizzard shad, a forage species in the lake, numerically dominated the collections by representing over 60% of the total in both CWIS sampling programs. Total impingement and entrainment rates generally have declined over the study period due primarily to the reduction in gizzard shad collection numbers. In contrast, white perch collection numbers have increased over the period and match the increase in the size of adult white perch samples from the lake. Generally, fluctuations in the impingement and entrainment rate have closely followed population densities as reported by cove rotenone studies.

Black crappie, a popular panfish, was the second most commonly impinged species with an average annual impingement number of 28,437 compared to an average of 116,646 for gizzard shad from 1979-1983. Estimated annual creel numbers of black crappie were always higher than impingement numbers. The percentage of small crappie (<100 mm) impinged has decreased since 1978, supporting the premise of a declining population which is consistent with other biological data. This population decline could possibly reflect a natural cyclic trend of the species or it possibly could be attributed to the lack of preferred habitat in the lake. Results of cove rotenone studies in 1984 have indicated a slight increase in the black crappie standing crop.

A comparison of impingement numbers to standing crop estimates of the lake indicated that the percentage of the population affected by impingement is very low. The average percentage of the gizzard shad standing crop that was removed annually by impingement was 0.38% by number and 0.32% by weight. For crappie, percentages averaged 3.1% (number) and 3.8% (weight). Values for other species were less than 1.0%. As generally found in new reservoirs, Lake Anna exhibited an initial high fish abundance during 1973 and 1974 followed by a decline in succeeding years. Since 1978, the mean standing crop of fishes in Lake Anna has remained relatively stable. The first station unit did not become operational until mid-1978; therefore, it seems apparent from standing crop comparisons that impingement from the power station has not caused significant reductions or fluctuations in the fish community.

A significantly greater number of fish (75% of the total) were impinged during the winter season. Lower water temperatures during the winter months tend to make fishes sluggish and therefore more susceptible to impingement. Water velocities recorded in front of the CWIS were less than 0.2 m/sec, and therefore, nearly all fish appear to be able to avoid the intake screens during other seasons. There is some evidence that fish in poorer condition during warmer seasons may be more susceptible to entrapment at the CWIS.

Goodyear's Equivalent Adult Analysis Model was used to determine the impact of entrainment on the Lake Anna fishery. It provided a conservative estimate of entrainment impact because of the moderate biological assumptions used in the analysis. The result of the model analysis indicated the percent cropping from the lake fish populations by the power station varied among years and species. Values ranged from a low of 0.01% (black crappie in 1978 and 1979 and sunfishes in 1982) to a high of 4.13% (gizzard shad in 1980). These values when compared with other studies are considered less than any that could cause a significant impact on the Lake Anna fishery.

Natural compensation, which forms an integral, if not the underlying foundation of modern fish management, should offset any individual losses from impingement and entrainment. The principle of compensation or the capacity of a population to ameliorate, in whole or in part, reductions in numbers is an operant reality for fish populations subjected to exploitation whether by the sport fishery, natural predators or impingement and entrainment. In general, when individuals, particularly larvae and juveniles, are removed from a population, the reproductive, survival and growth rates among the remaining individuals tend to increase. In this manner the sheer numbers of individuals impinged or entrained by the North Anna CWIS are not necessarily indicative of adverse environmental impact. This report demonstrates by comparing data from other biological programs and by the use of a model that the effects of impingement and entrainment at the CWIS of North Anna Power Station are minimal and do not seem to adversely affect the fish populations of Lake Anna.

1.0 INTRODUCTION

The cooling water intake structure (CWIS) at an electric generating station is one area where contact between the environment and the power station is most evident. The environmental influences of operation are readily observable here because they are primarily physical in nature. In a once-through cooling system, a relatively large volume of water is utilized to condense the steam that is produced to turn the electric turbines. This water is pumped from a source, such as a lake or river, by a circulating water pump (CWP). Intake screens in front of the CWP's at power stations (usually 9.5 mm mesh) filter the water and provide protection to the cooling system from damage and clogging. Two fundamental biological effects at CWIS's are impingement, the entrapment of organisms in front of the screens, and entrainment, the passage of organisms through the intake water system.

Some of the fish that are too large to pass through the intake screen mesh may stay in front of the screens and eventually will tire and become impinged. Screens are periodically cleaned using a spray wash system and the impinged fish washed from the screens are either discarded or returned to the waterway. Observed and/or latent mortality of these fish may approach 100%, although some CWIS modifications at power stations have been designed to mitigate the environmental influence (White and Brehmer 1976; Scotton and Anson 1977; Schneeberger and Jude 1981; Zeitoun et al. 1981; and Hadderingh 1982). The number of fishes impinged is a function of many variables (water temperature, intake design, etc.) and the significance of the numbers should be evaluated only with reference to the particular site in question. Entrainment refers to those organisms that are smaller than the screen mesh and pass through the cooling system. The degree of mechanical, thermal and chemical activity within the cooling system is the key factor in determining survival rates (Ecological Analysts, Inc. 1977). Entrainment can result in a reduction in the ichthyoplankton (fish eggs and larvae) population, which in effect, is similar to an increase in natural predation. Predation and other mortality causes affecting larval populations are important factors in determining the stability of the adult fishery stock and its recruitment success.

Considerable information on impingement and entrainment has been published. Four national workshops have been held and proceedings have been printed listing various methodologies, program results, impact assessments, design modifications and survival estimates for many site locations in the country [held 1972, 1973, 1976, 1977; Loren P. Jensen, Editor; available through either Electric Power Research Institute (EPRI), Palo Alto, California; or EA Engineering, Science and Technology, Inc., Melville, N. Y. (formerly Ecological Analysts, Inc.)]. Also EPRI has published several annotated bibliographies on impingement and entrainment (EPRI, EA-1049 1979; EPRI, EA-1050 1979; EPRI, EA-1855 1981).

The main objective of biological studies at intakes is to obtain sufficient information to determine if the technology selected by the industry is the best available to minimize adverse environmental impact (EPA 1976). A guidance manual has been developed by EPA to assist industry in evaluating the potential adverse impact of cooling water intake structures (EPA 1977). Generally, regulatory agencies have recognized that a certain degree of influence at intakes can be acceptable and that each case must be evaluated on a site specific basis.

Impact assessment from a biological standpoint should be related to the total effect on the ecosystem and not solely on numbers impinged or entrained. This holistic approach allows scientists to consider the resiliency of biological systems from imposed perturbations. The present stability of an ecosystem and the extent of introduced stress to the system are important considerations in the final analysis of total effect on the environment (Zeitoun et al. 1980).

This impingement and entrainment report covers work conducted from 1978-1983 in accordance with Section 316(b) of Public Law 92-500 of the Federal Water Pollution Control Act Amendments of 1972, and in compliance with the Nuclear Regulatory Commission's Environmental Technical Specifications (Section 5.6.1.1) for North Anna Power Station (Docket Nos. 50-338 and 50-339), and the Virginia State Water Control Board's NPDES Permit No. VA0052451 under Special Conditions: Environmental Studies. The sampling program conducted and the amount of data available for analysis, as submitted in this report, should allow for a holistic evaluation of the environmental influence of the North Anna Power Station intake structure on Lake Anna, Virginia. A 100% mortality of impinged fish and entrained ichthyoplankton is assumed in this study, representing a worst case estimate of cropping by the power station.

2.0 SITE AND ENVIRONMENTAL DESCRIPTION

2.1 Physical and Hydrological Characteristics

The Lake Anna dam (latitude 38°42'10", longitude 77°42'39") was closed by Virginia Power in 1972 impounding 53 km^2 of the North Anna River basin (Figure 2.1.1). This created a reservoir source of cooling water for the North Anna Power Station and a smaller Waste Heat Treatment Facility (WHTF). Both of these bodies of water share the burden of dissipating waste heat from the power station to the atmosphere though the major portion is dissipated within the WHTF. Lake Anna has since been utilized to a large extent by the public for recreation and is being considered for hydroelectric power production.

Lake Anna has a surface area of 38.85 km^2 (9600 acres), a volume of $3.0 \times 10^8 m^3$ and an average depth of 7.6 m. The maximum depth at the dam is 24 m. The WHTF has a surface area of 13.76 km^2 (3400 acres), a volume of $7.5 \times 10^7 m^3$, an average depth of 5.5 m and a maximum depth of 15 m in the vicinity of the dikes. The average annual inflow to the lake is about 7.6 m^3/s and lake level is maintained by three radial gates in the dam and two near-surface skimmers. The minimum allowable discharge to the river is 1.1 m^3/s but the annual discharge averages 6.2 m^3/s. The annual average evaporation from the lake surface is estimated to be 1.7 m^3/s. The design elevation of the lake is 76.2 m (250 feet) above mean sea level; the highest recorded lake level during the study period was 76.5 m (251.0 ft.) (January 28, 1976) and the lowest recorded level was 75.4 m (247.4 ft.) (October 24-25, 1977).

Lake Anna is 27 km (17 miles) long with over 438 km (272 miles) of shoreline and is located in Louisa, Spotsylvania and Orange Counties. It is in the headwaters of the York River and drains 888 km^2 (York River drainage = 6889 km^2) (Figure 2.1.2). A tributary reservoir, Lake Anna is typified by a relatively small drainage area/surface area ratio (22.9) and a long hydraulic retention time (465 days). The efficiency of a water system to process and trap organic input is critically dependent on the length of the retention time. Reservoirs with long retention times are generally dominated by autochthonous production.

This lake basin is characterized by igneous and metamorphic rock underlayments (Figure 2.1.3) that typically produce soft to moderately hard sodium bicarbonate water. Iron is often present in troublesome amounts in groundwater, along with sulfides and acidic conditions. Three inactive pyrite mines and mining spoils piles (0.12 denuded km^2) are contributing high concentrations of dissolved metals and acid leachate to Contrary Creek, which drains 60 km^2 of Louisa County and discharges into Lake Anna 3 km upstream from the power station. The average annual flow of Contrary Creek is 0.2 m^3/s where it empties into Lake Anna.

The effects of acid mine drainage from Contrary Creek were evident for several miles downstream prior to the impoundment of Lake Anna. However, the reservoir has ameliorated the negative effects of peak pollutants downstream from the dam by diluting the influent.

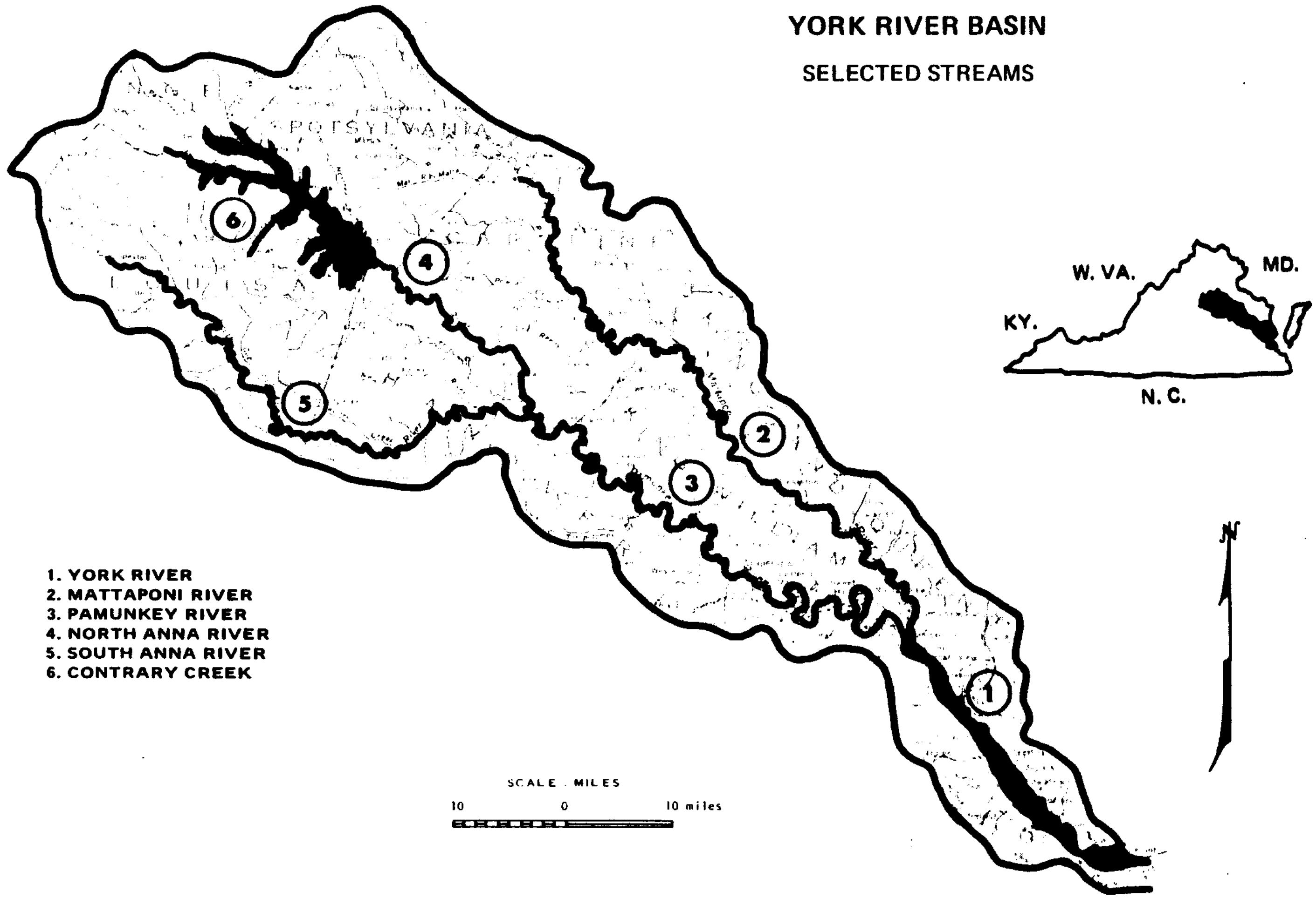


FIGURE 2.1.2. YORK RIVER BASIN (VSWCB, WATER QUALITY INVENTORY, 305(b) REPORT, 1976, p. 328).

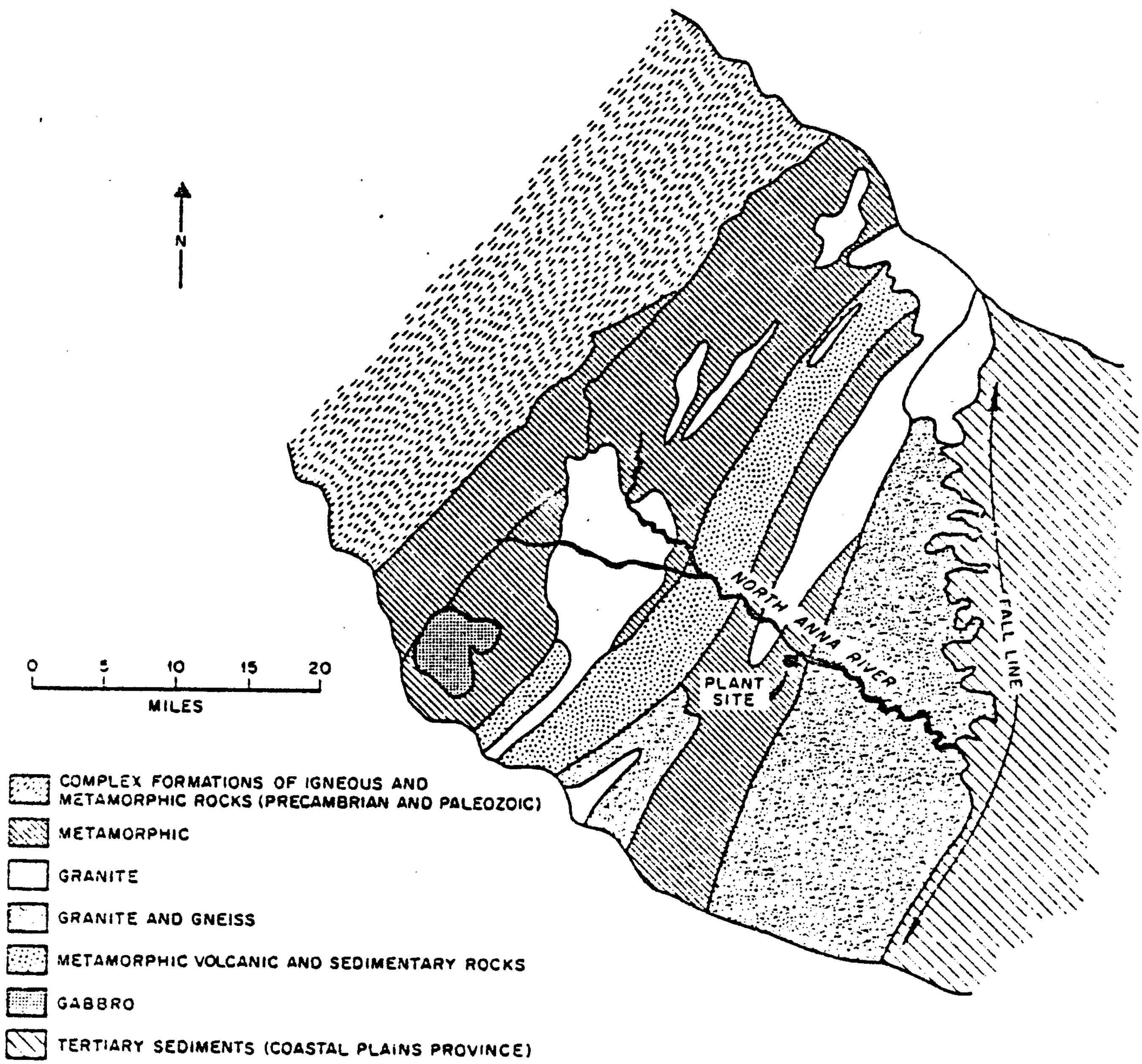


FIGURE 2.1.3. GEOLOGIC MAP OF THE PIEDMONT PROVINCE IN THE VICINITY OF THE NORTH ANNA POWER STATION, (VIRGINIA DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT/DIVISION OF WATER RESOURCES,1970).

2.2 Limnetic Characteristics

Lake Anna is an oligo-mesotrophic, second order dimictic reservoir by definition (Reid and Wood 1976). Anoxia occurs throughout the hypolimnion in Lake Anna during summer stratification to varying degrees depending on the oxygen demand of organic decomposition and aquatic life present. Because of thermal density resistance to mixing, stratification usually persists through the summer in Lake Anna until cooler inflows and weather conditions produce the fall overturn.

Surface intake cove water temperatures recorded hourly by continuous recorders (Endeco) were tabulated; daily means for 1978-1983 are shown in Figures 2.2.1-2.2.6. Temperature and dissolved oxygen isopleths for the intake station are shown in Figures 2.2.7-2.2.12, and the third plot in each figure shows the level of station operation (% of total power load and pumping capacity). Station operation is discussed in more detail in Section IV. In general, the lake was vertically homothermous from mid-September until April. Thermal stratification was usually evident to some degree from May-August but appeared to be the most pronounced in 1982 from July-August (Figure 2.2.11). This period of pronounced stratification coincided with anoxia below 8m contrasting with the results for 1983 (Figure 2.2.12) at which time there was a higher degree of station pumping and lake circulation.

In general, the headwaters of the York River Basin have been known for excellent water quality attributed to low level development and the general paucity of municipal and industrial dischargers. Annual means for nitrate nitrogen, ammonia nitrogen and total phosphorus are shown in Figures

2.2.13-2.2.15, respectively. The location of this reservoir in the headwaters of the drainage basin may be related to generally low levels of total phosphorous (less than 0.05 ppm) in the lake water; the geologic nature of this region may account for the typically low alkalinity levels (0-40 ppm as $CaCO_3$). Both of these parameters indicate low to fair organic productivity in Lake Anna, but within the reservoir, the shallow upper reaches are more fertile than the lower reservoir and are typified by higher alkalinities and levels of autochthonous and allochthonous input. Appendix A gives a complete listing of environmental reports available describing the current and historical physical, chemical and biological parameters of Lake Anna and the North Anna River.

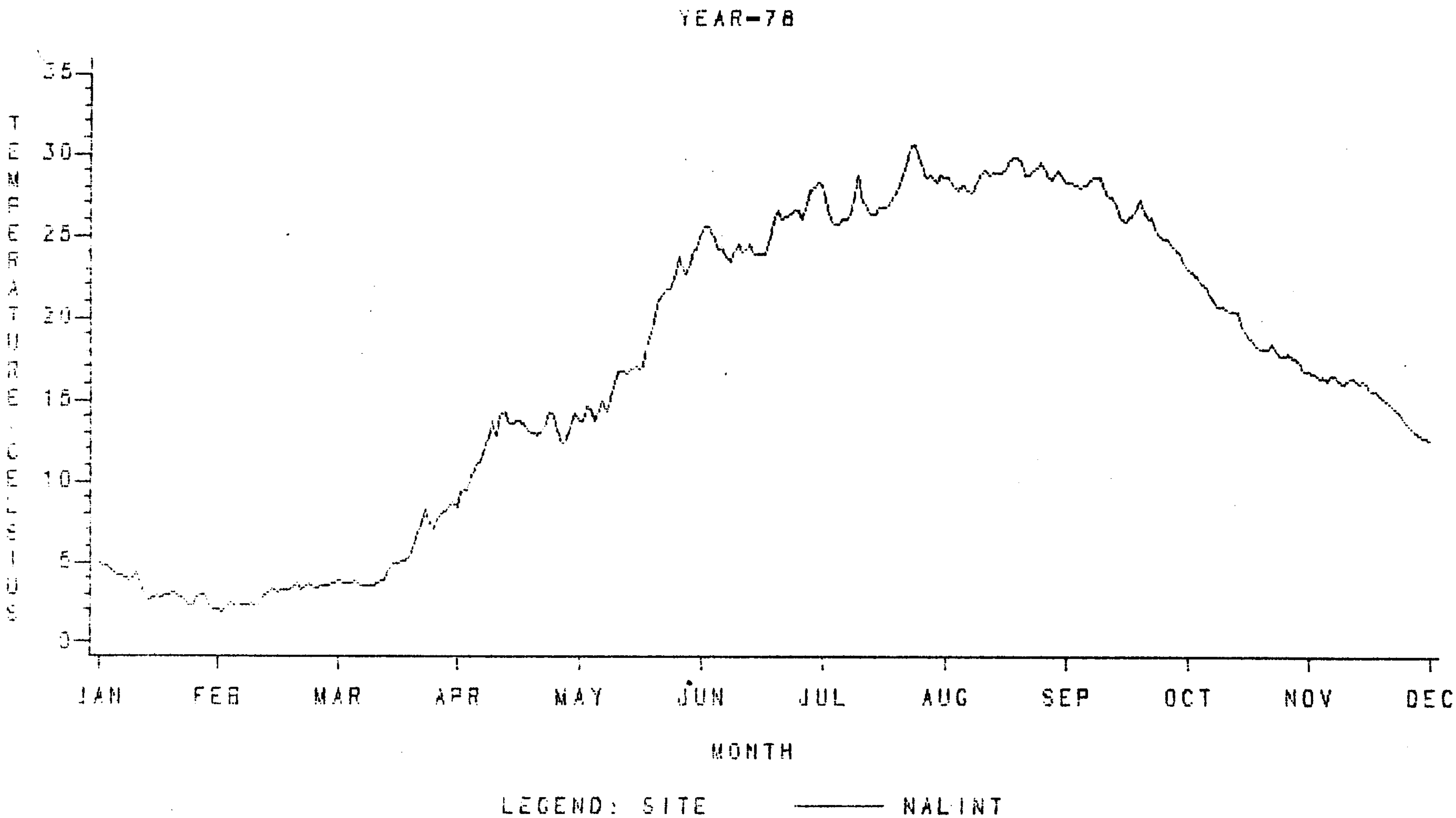


FIGURE 2.2.1. DAILY MEAN WATER TEMPERATURES FROM INTAKE ENDECO NALINT. STRAIGHT OR MISSING LINE SEGMENTS INDICATE MISSING DATA.

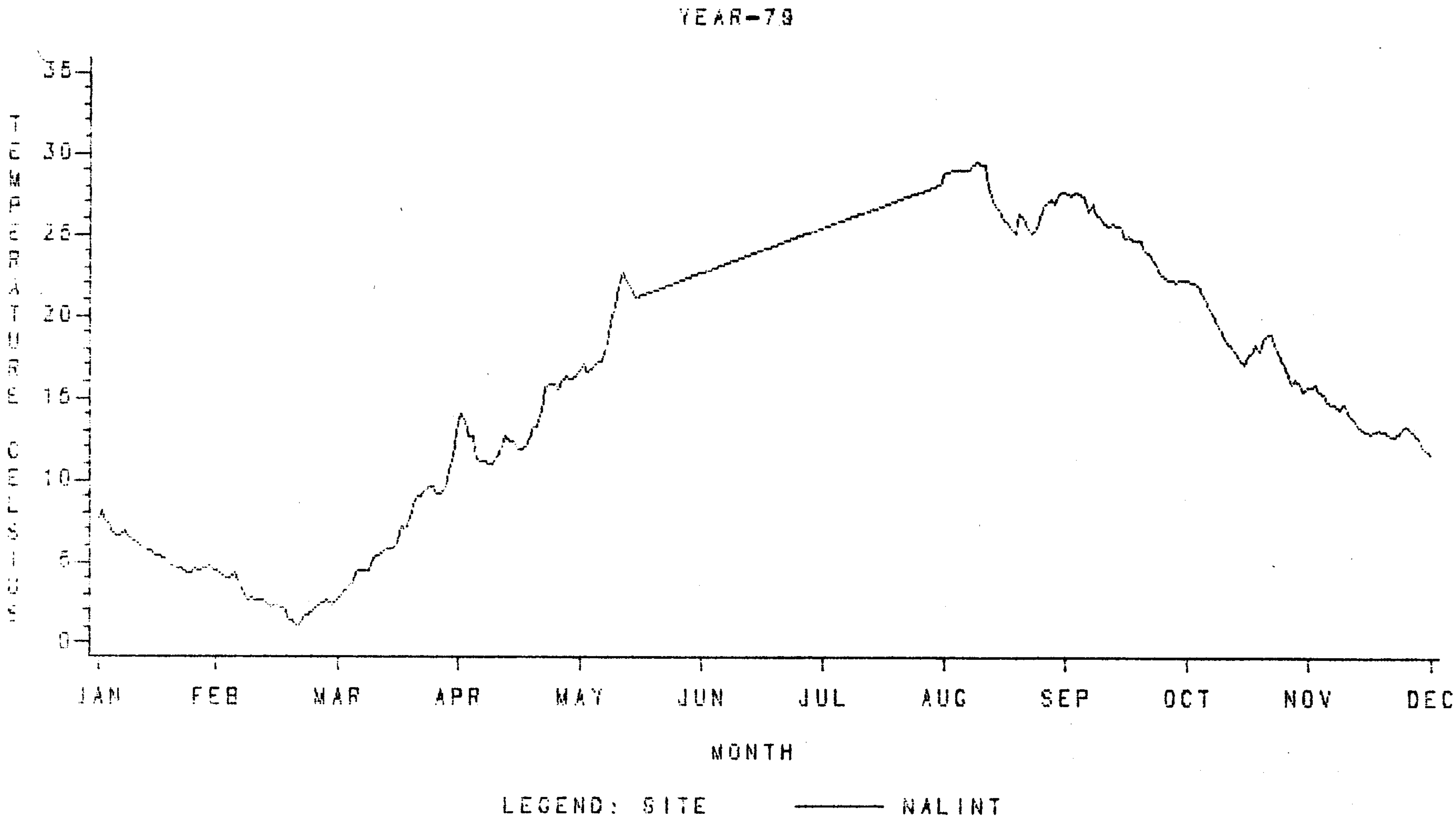


FIGURE 2.2.2. DAILY MEAN WATER TEMPERATURES FROM INTAKE ENDECO NALINT. STRAIGHT OR MISSING LINE SEGMENTS INDICATE MISSING DATA.

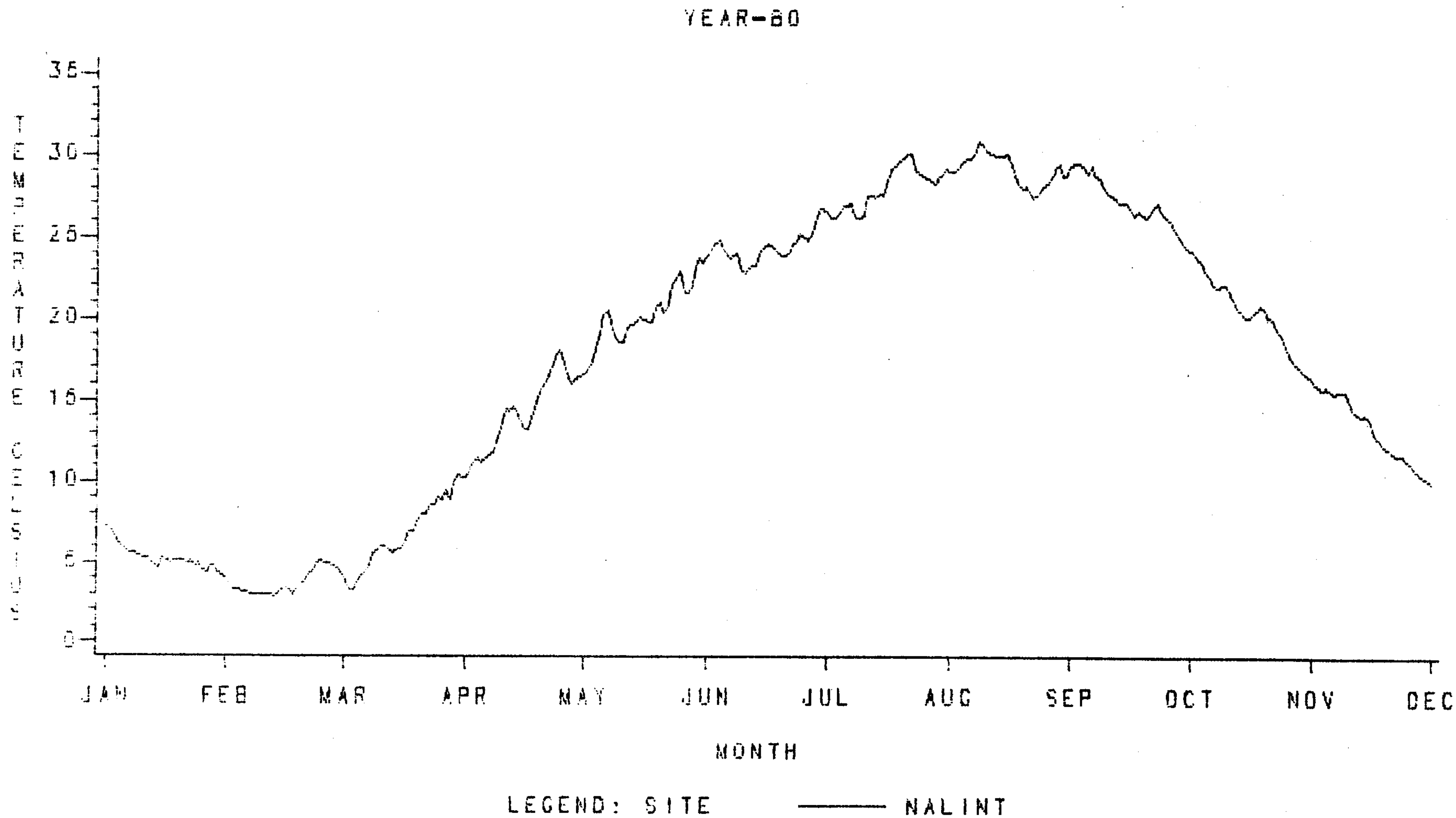


FIGURE 2.2.3. DAILY MEAN WATER TEMPERATURES FROM INTAKE ENDECO NALINT. STRAIGHT OR MISSING LINE SEGMENTS INDICATE MISSING DATA.

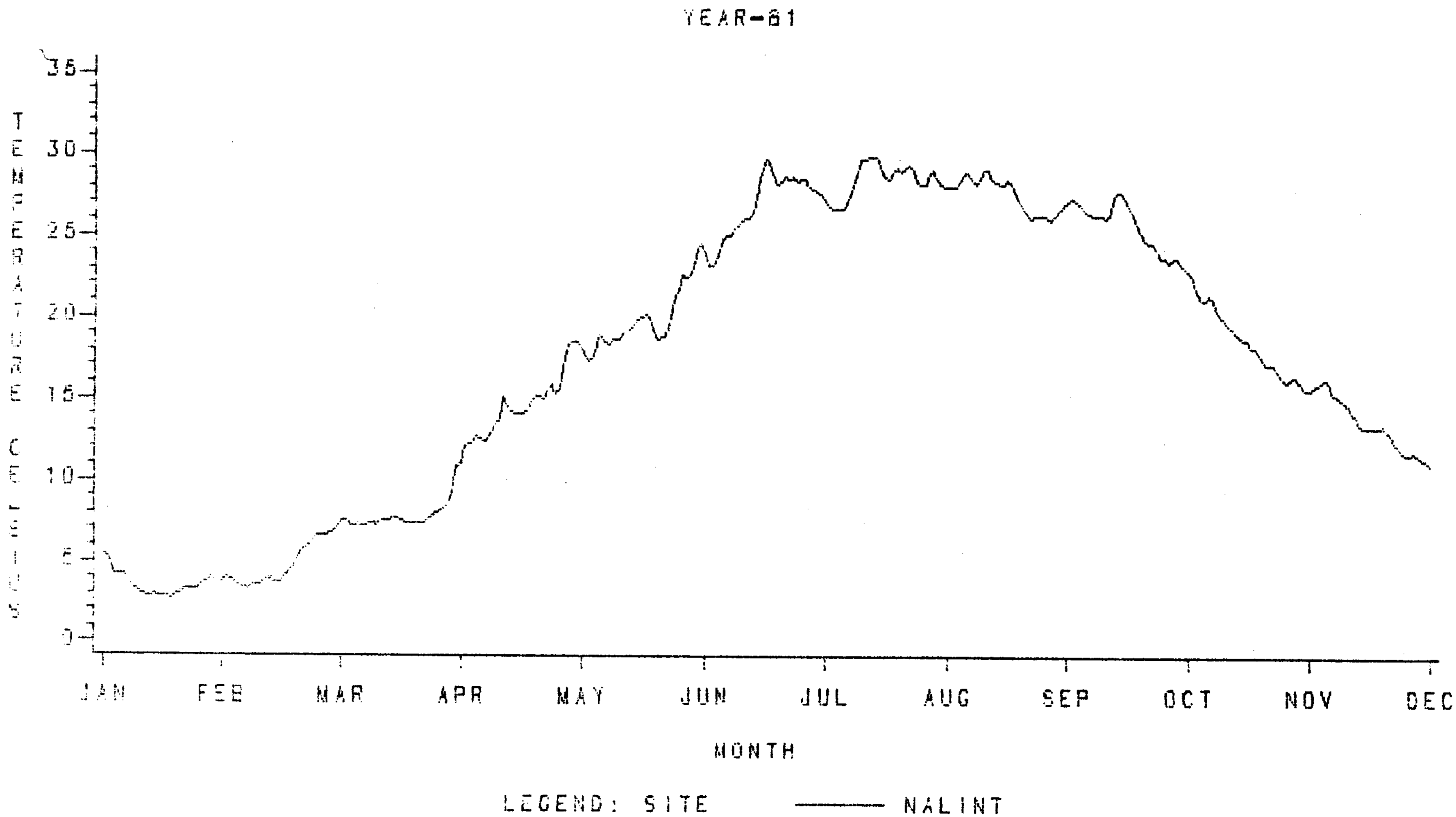


FIGURE 2.2.4. DAILY MEAN WATER TEMPERATURES FROM INTAKE ENDECO NALINT. STRAIGHT OR MISSING LINE SEGMENTS INDICATE MISSING DATA.

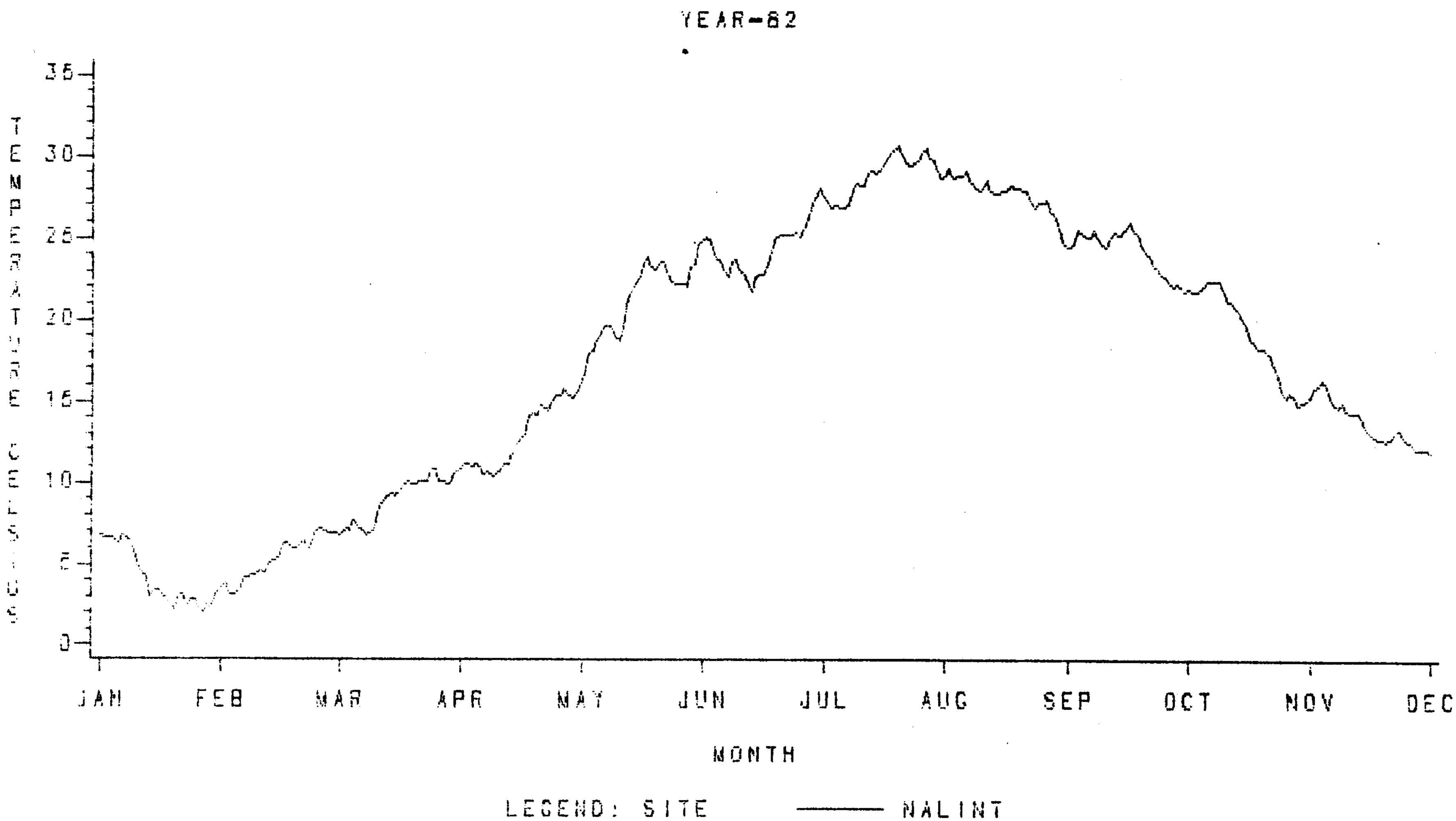


FIGURE 2.3.5. DAILY MEAN WATER TEMPERATURES FROM INTAKE ENDECO NALINT. STRAIGHT OR MISSING LINE SEGMENTS INDICATE MISSING DATA.

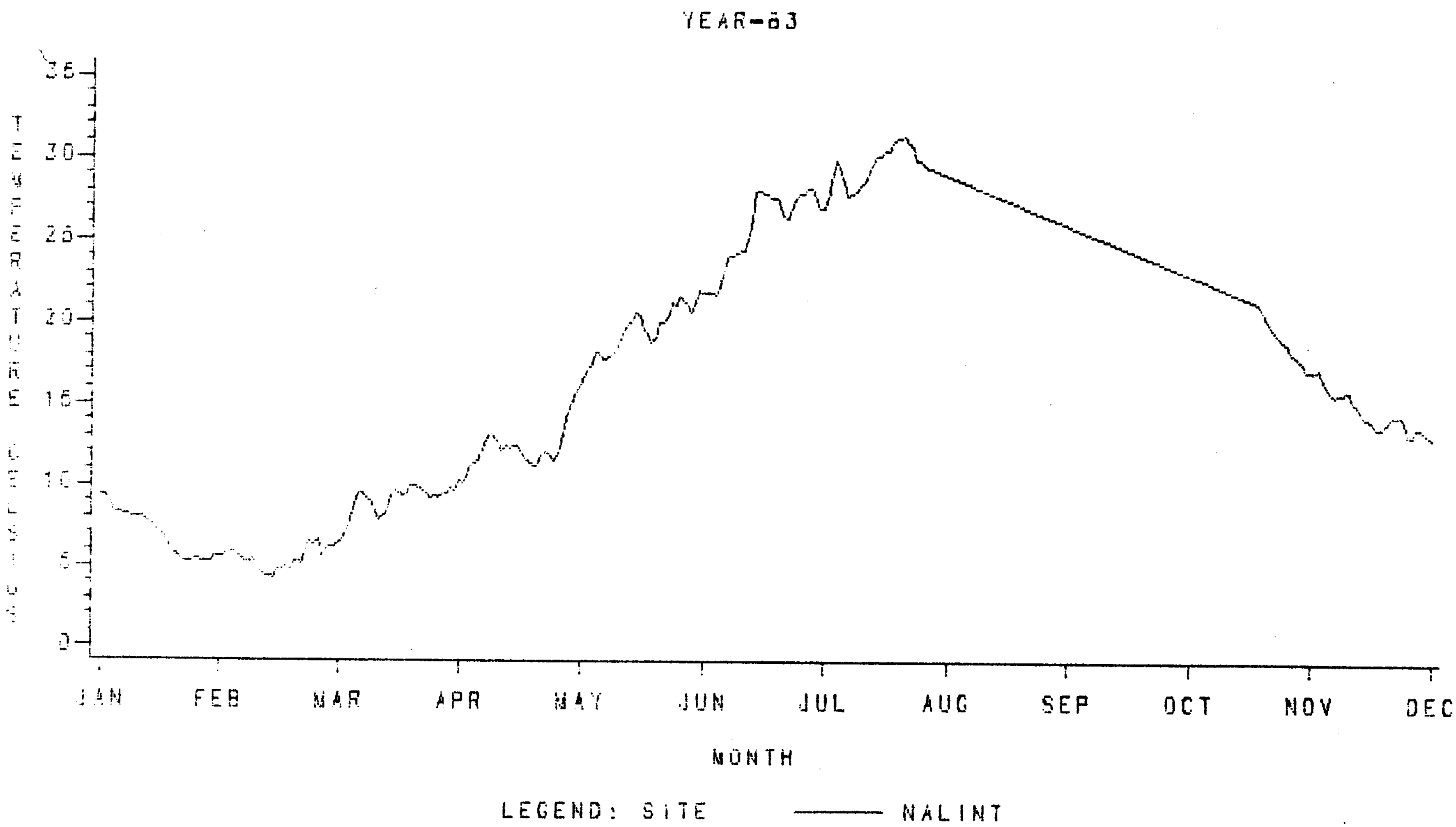


FIGURE 2.2.6. DAILY MEAN WATER TEMPERATURES FROM INTAKE ENDECO NALINT. STRAIGHT OR MISSING LINE SEGMENTS INDICATE MISSING DATA.

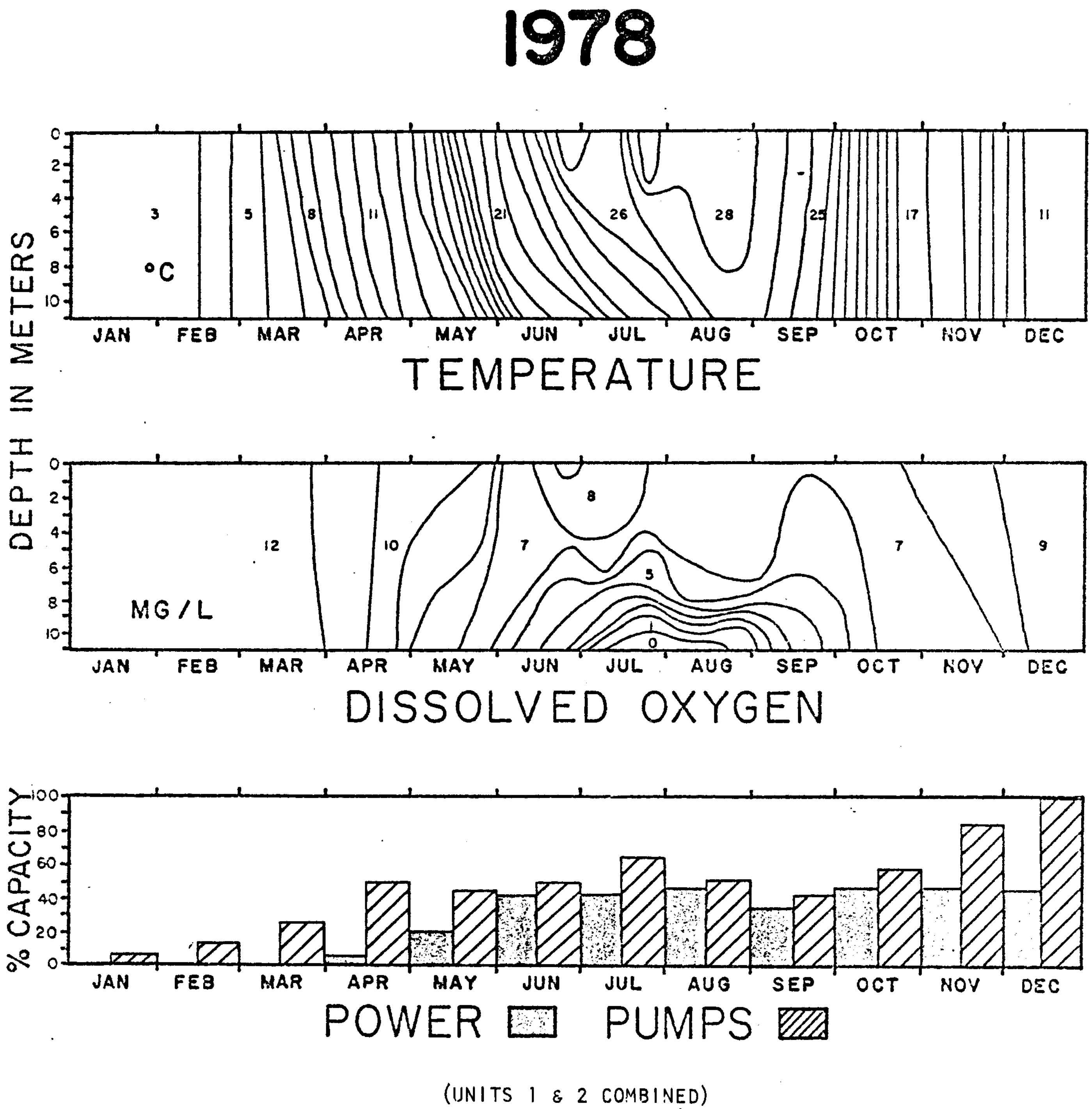
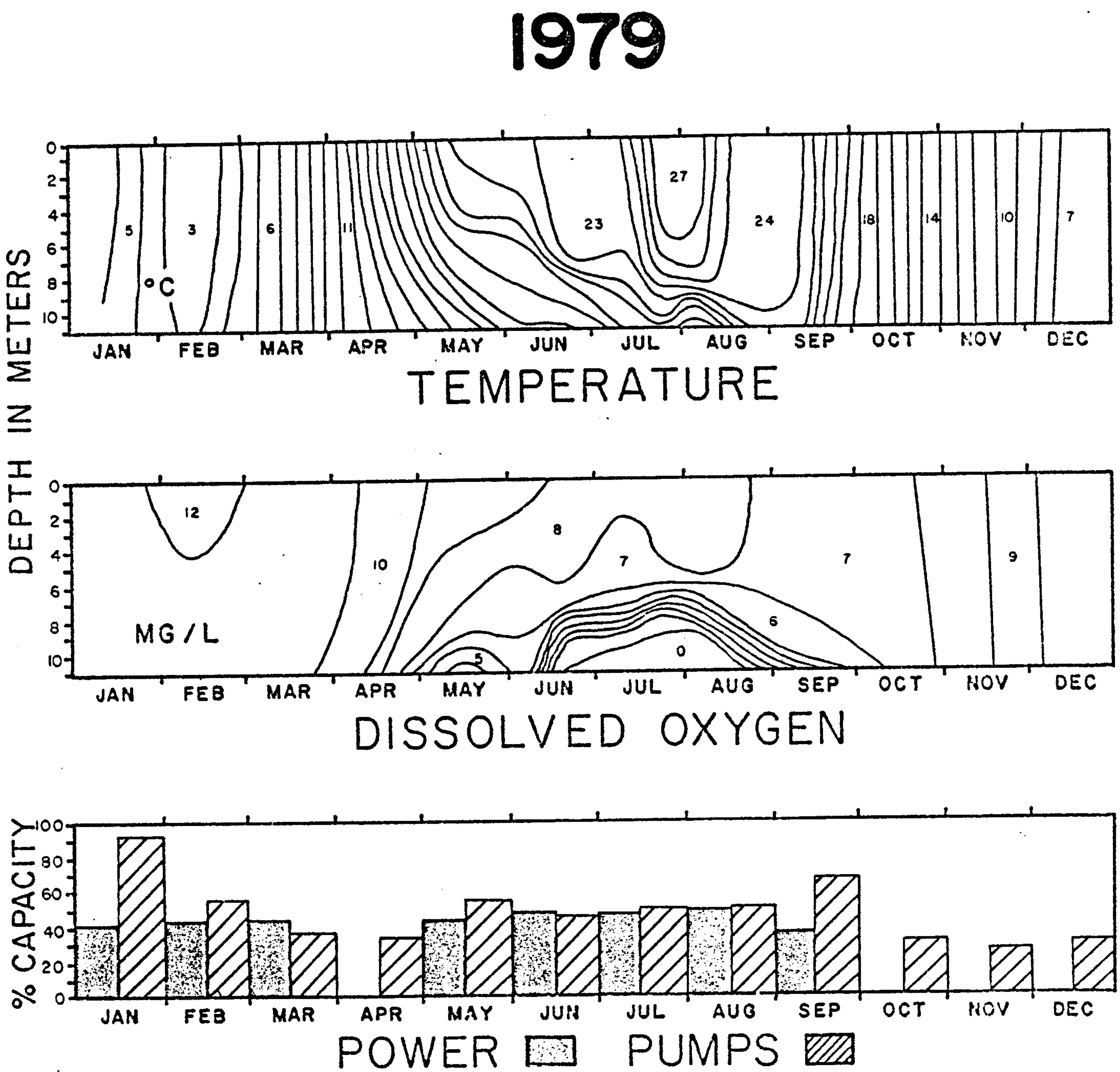
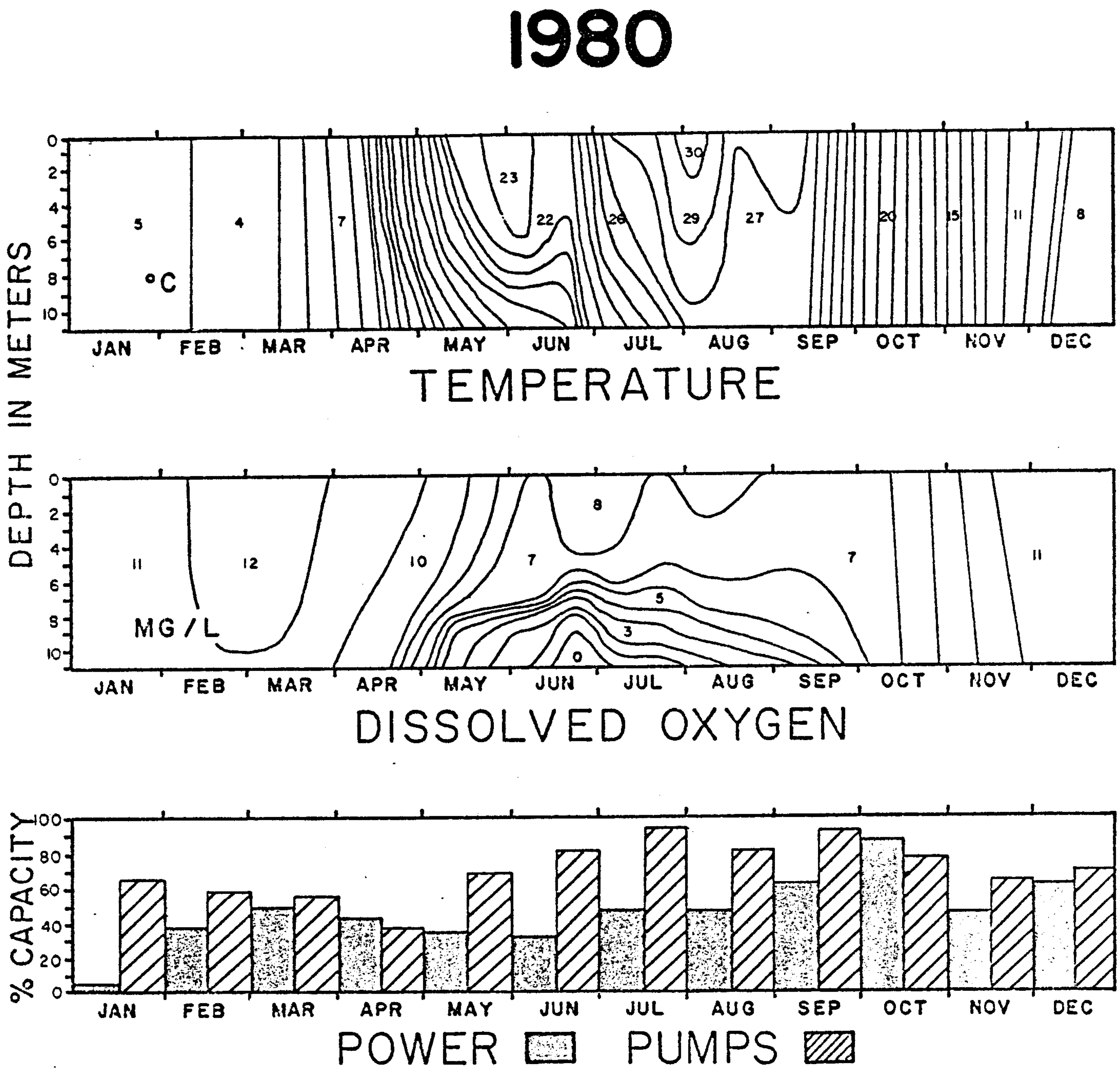


FIGURE 2.2.7. ANNUAL TEMPERATURE AND DISSOLVED OXYGEN CYCLES BY MONTH AT THE INTAKE STATION, AND CORRESPONDING NORTH ANNA POWER STATION OPERATION (% OF TOTAL POWER LOAD AND PUMPING CAPACITY BY MONTH).



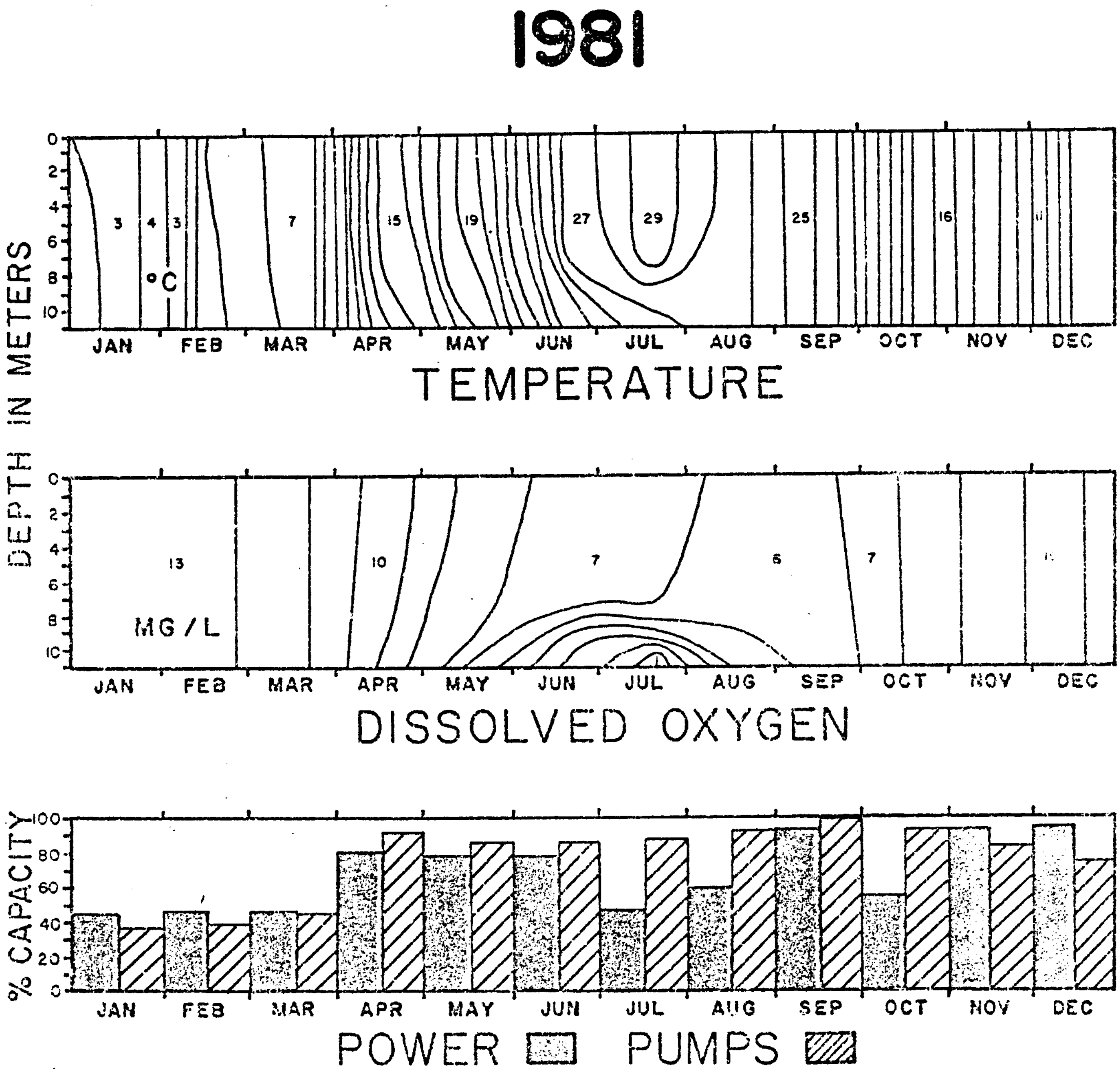
(UNITS 1 & 2 COMBINED)

FIGURE 2.2.8. ANNUAL TEMPERATURE AND DISSOLVED OXYGEN CYCLES BY MONTH AT THE INTAKE STATION, AND CORRESPONDING NORTH ANNA POWER STATION OPERATION (% OF TOTAL POWER LOAD AND PUMPING CAPACITY BY MONTH).



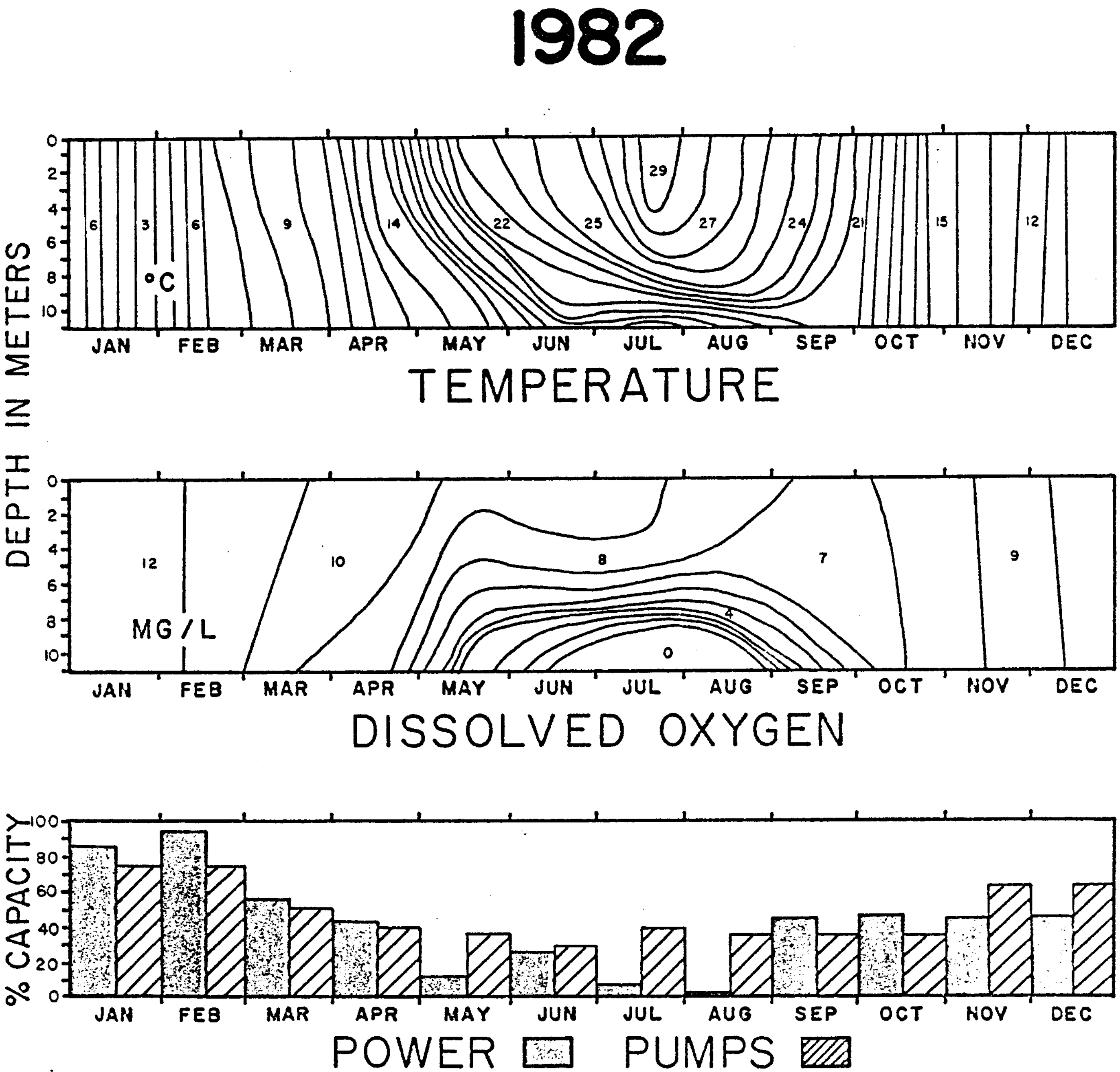
(UNITS 1 & 2 COMBINED)

FIGURE 2.2.9. ANNUAL TEMPERATURE AND DISSOLVED OXYGEN CYCLES BY MONTH AT THE INTAKE STATION, AND CORRESPONDING NORTH ANNA POWER STATION OPERATION (% OF TOTAL POWER LOAD AND PUMPING CAPACITY).



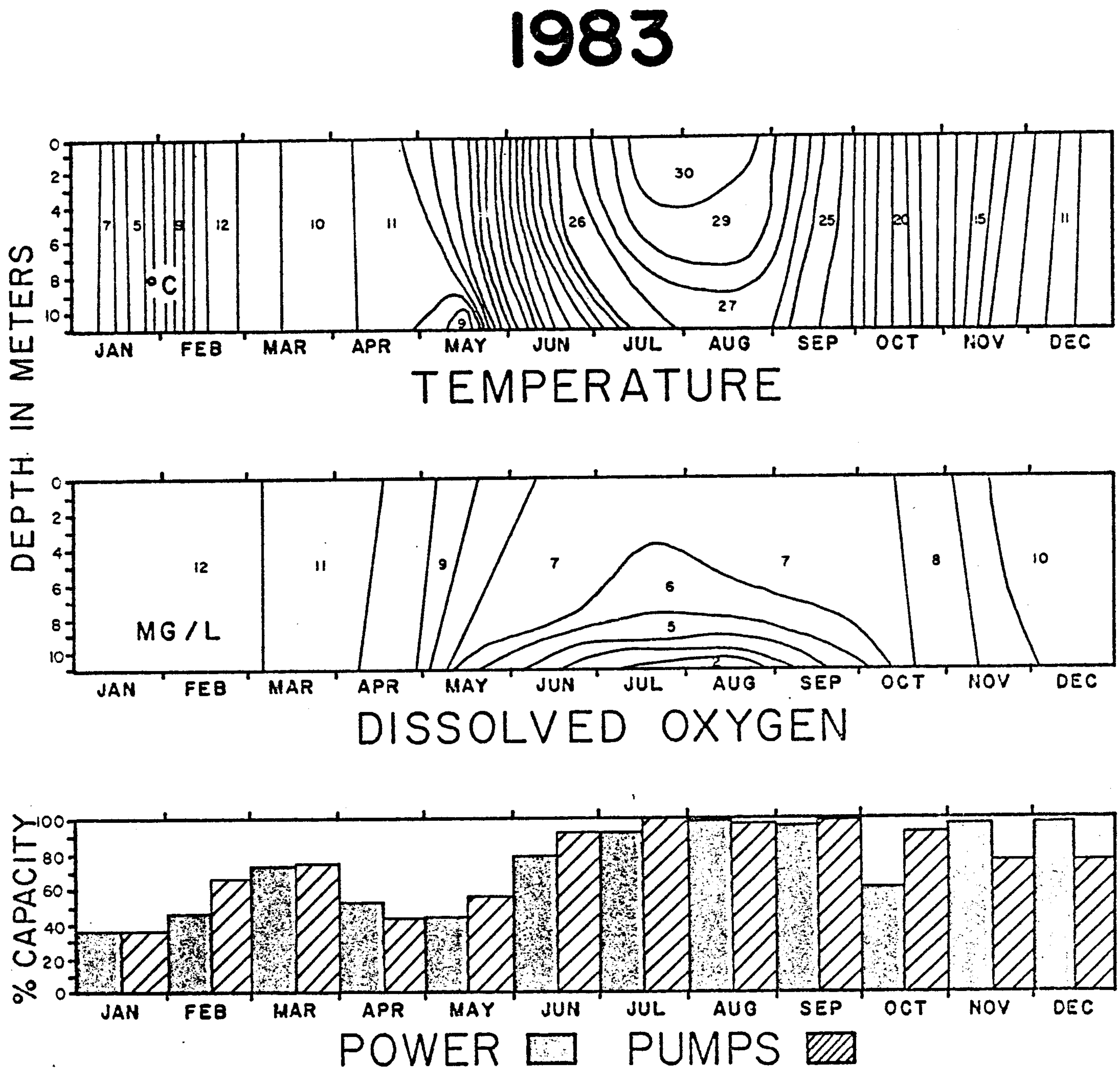
(UNITS 1 & 2 COMBINED)

FIGURE 2.2.10. ANNUAL TEMPERATURE AND DISSOLVED OXYGEN CYCLES BY MONTH AT THE INTAKE STATION, AND CORRESPONDING NORTH ANNA POWER STATION OPERATION (% OF TOTAL POWER LOAD AND PUMPING CAPACITY BY MONTH).



(UNITS 1 & 2 COMBINED)

FIGURE 2.2.11. ANNUAL TEMPERATURE AND DISSOLVED OXYGEN CYCLES BY MONTH AT THE INTAKE STATION, AND CORRESPONDING NORTH ANNA POWER STATION OPERATION (% OF TOTAL POWER LOAD AND PUMPING CAPACITY BY MONTH).



(UNITS 1 & 2 COMBINED)

FIGURE 2.2.12. ANNUAL TEMPERATURE AND DISSOLVED OXYGEN CYCLES BY MONTH AT THE INTAKE STATION, AND CORRESPONDING NORTH ANNA POWER STATION OPERATION (% OF TOTAL POWER LOAD AND PUMPING CAPACITY BY MONTH).

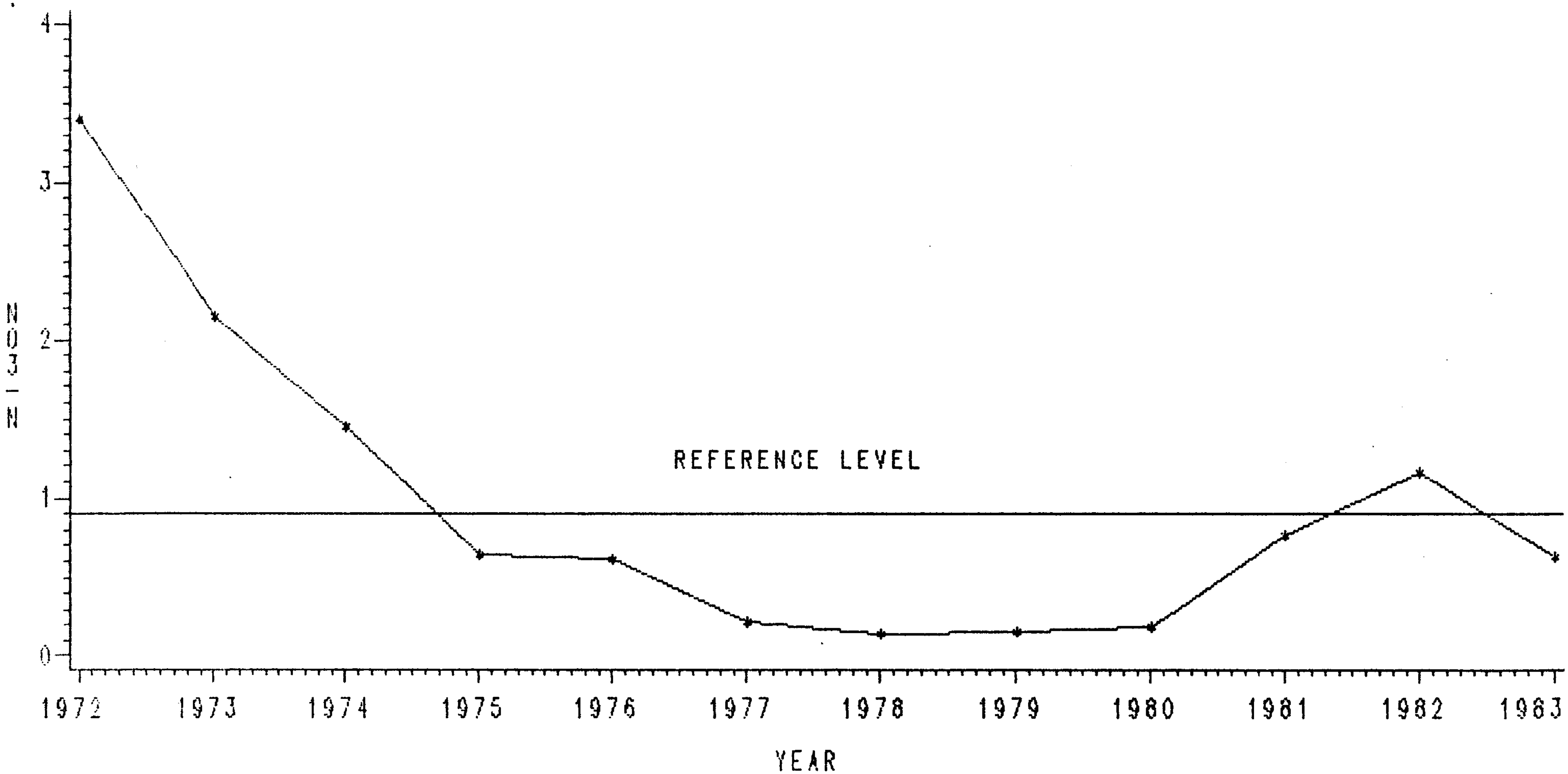


FIGURE 2.2.13. ANNUAL NO3-N MEANS FOR LAKE ANNA SINCE 1972. CONTRARY CREEK DATA WERE NOT USED. FOR AN EXPLANATION OF REFERENCE LEVEL, SEE THE 1976 VSWCB PUBLICATION ***WATER QUALITY INVENTORY*** (305(B) REPORT), SECTION ON THE YORK RIVER BASIN.

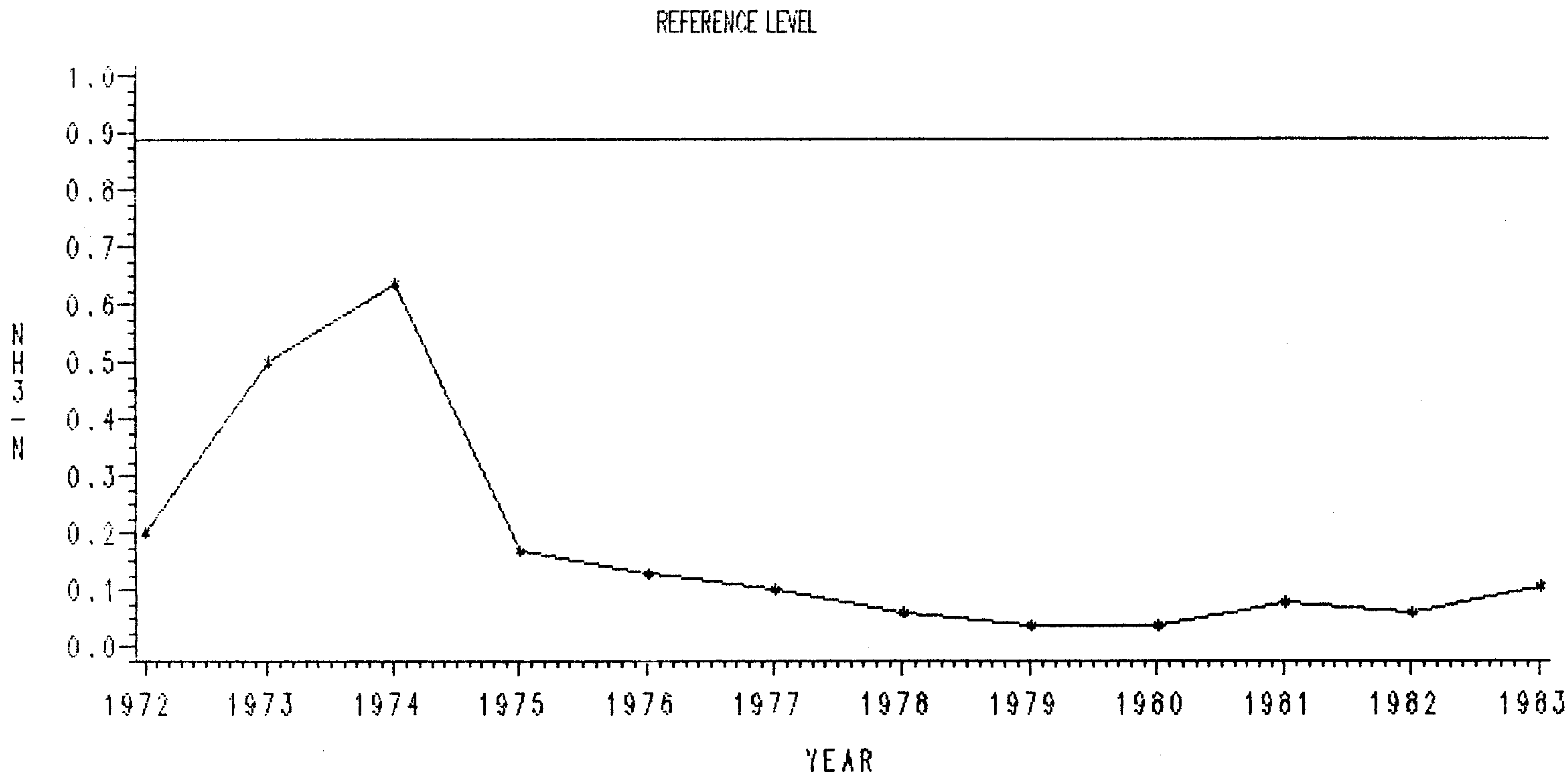


FIGURE 2.2.14. ANNUAL NH3-N MEANS FOR LAKE ANNA SINCE 1972. CONTRARY CREEK DATA WERE NOT USED. FOR AN EXPLANATION OF REFERENCE LEVEL, SEE THE 1976 VSWCB PUBLICATION ***WATER QUALITY INVENTORY*** (305(B) REPORT), SECTION ON THE YORK RIVER BASIN.

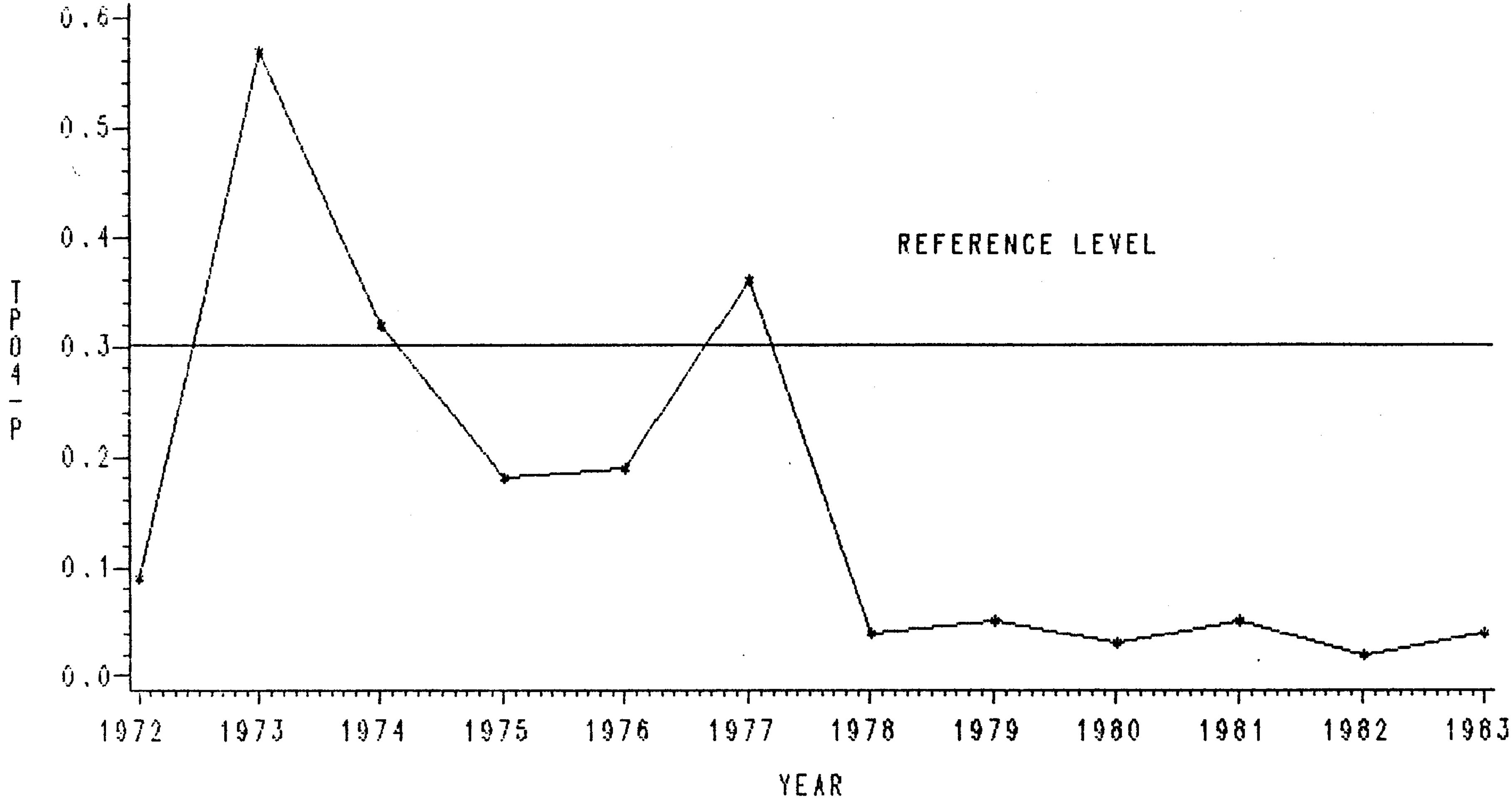


FIGURE 2.2.15. ANNUAL T-PO4-P MEANS FOR LAKE ANNA SINCE 1972. CONTRARY CREEK DATA WERE NOT USED. EXPLANATION OF REFERENCE LEVEL, SEE THE 1976 VSWCB PUBLICATION ***WATER QUALITY INVENTORY*** (305(B) REPORT), SECTION ON THE YORK RIVER BASIN.

3.0 STATION DESCRIPTION

3.1 Location & General Site Features

The North Anna Power Station was constructed in Louisa County in central Virginia 48 km (30 miles) northwest of Richmond and 64 km (40 miles) east of Charlottesville. The two units of the station are located on the south bank of a lake formed by a dam on the North Anna River 0.8 km west of the common junction of Louisa, Hanover and Spotsylvania Counties (Figure 3.1.1). A total of 76 km^2 (18,643 acres) of land was purchased in these three counties for construction of a dam and reservoir, the power station, service roads, a spur railroad, and 1.5m (vertical) of surcharge capability.

Unit 1 was under construction beginning in 1969 and was ready for commercial operation in April 1978. Unit 2 construction began in March 1970 and was completed in August of 1980. Both units were expected to operate at annual average capacity of 65%, and thus far, Unit 1 is slightly underachieved, while Unit 2 is averaging slightly more than the expected 65%. The thermal conversion efficiency is approximately 33% for each unit.

3.2 Heat Exchanger Components

The station has a once-through cooling system (circulating-water system) to dissipate waste heat from the turbine condensers and from the auxiliary cooling systems to the environment (Figure 3.2.1). When both units are operating, water is taken from Lake Anna at a rate of about 117 m^3/s (1,858,000 gpm), circulated through the turbine condensers and service water system, and returned to the reservoir via the WHTF. Appendix B contains technical specifications for some of the station components associated with the intake structure. During operation, the heat generated in each reactor is transferred through the primary-coolant system to the steam generators. Units 1 and 2 each have three separate closed-cycle loops with one turbine-generator per loop. The steam generators transfer the heat from the primary-coolant system (around 302°C under 2235 PSI) to produce steam at a constant pressure in the secondary system. This steam is transferred through the closed-cycle secondary loops to the steam turbines, which drive the generators to produce electricity. After passing through the turbines, the spent steam is condensed and returned to the secondary sides of the steam generators to repeat the cycle. The station's NPDES permit limit is 13.5×10^9 Btu of waste heat per hour into the cooling water effluent (equivalent to about 66% of the total thermal power generated in the core). Units 1 & 2 have a design NSSS rating of 2910 MWt but is currently licensed to operate at the NSSS rating of 2785 MWt. The maximum ΔT across the condensers during the summer is 8.0° C (14.5° F), and during the winter predicted is 10.2°C (18.3°F).

3.3 Intake Structure

The cooling water for both the condenser circulating water system and the service water system is withdrawn from Lake Anna through two screenwells (one screenwell per unit) located in a cove north of the station. Each screenwell contains four individual bays, each bay (Figure 3.3.1) equipped with a trash rack, a traveling screen, and a vertical motor driven circulating water pump. The trash racks consist of 1.3 cm wide by 8.9 cm thick vertical bars spaced 10.2 cm on center (the velocity of the flow through the trash racks is about 0.2 m/s (1 fps) (Table 3.3.1). The traveling screens, constructed of 14-gage wire with 9.5 mm square openings, are designed to rotate once every 24 hours or whenever a predetermined pressure differential exists across the screens. Debris collected by the trash racks are removed by horizontally traversing mechanical rakes and then collected in hoppers which discharge the debris into wire baskets for disposal as solid waste. Debris and fish collected by the traveling screens are washed into wire baskets for disposal as solid waste.

Table 3.3.1. Intake water velocities (m/s) measured at each bay (approximately 5m out from trash racks) during two-unit operation, 9/30/81.

Depth (meters)	*Circulating Water Pump (4 Pumps/Unit) Unit 1 1	2	3	4	Unit 2 5	6	7	8
Sfc	.12	.14	.15	.16	.17	.16	.18	.16
1	.13	.24	.15	.21	.19	.21	.21	.18
2	.18	.21	.19	.22	.20	.19	.19	.17
3	.18	.21	.19	.22	.21	.24	.20	.17
4	.18	.18	.18	.23	.20	.21	.18	.21
5	.18	.18	.18	.22	.19	.22	.19	.19
6	.12	.21	.19	.19	.15	.23	.22	.16
7	.18	.15	.22	.21	.18	.19	.19	.13
8	.15	.18	.17	.21	.18	.21	.16	.12

*Each pump rated at 13.9 m^3/s

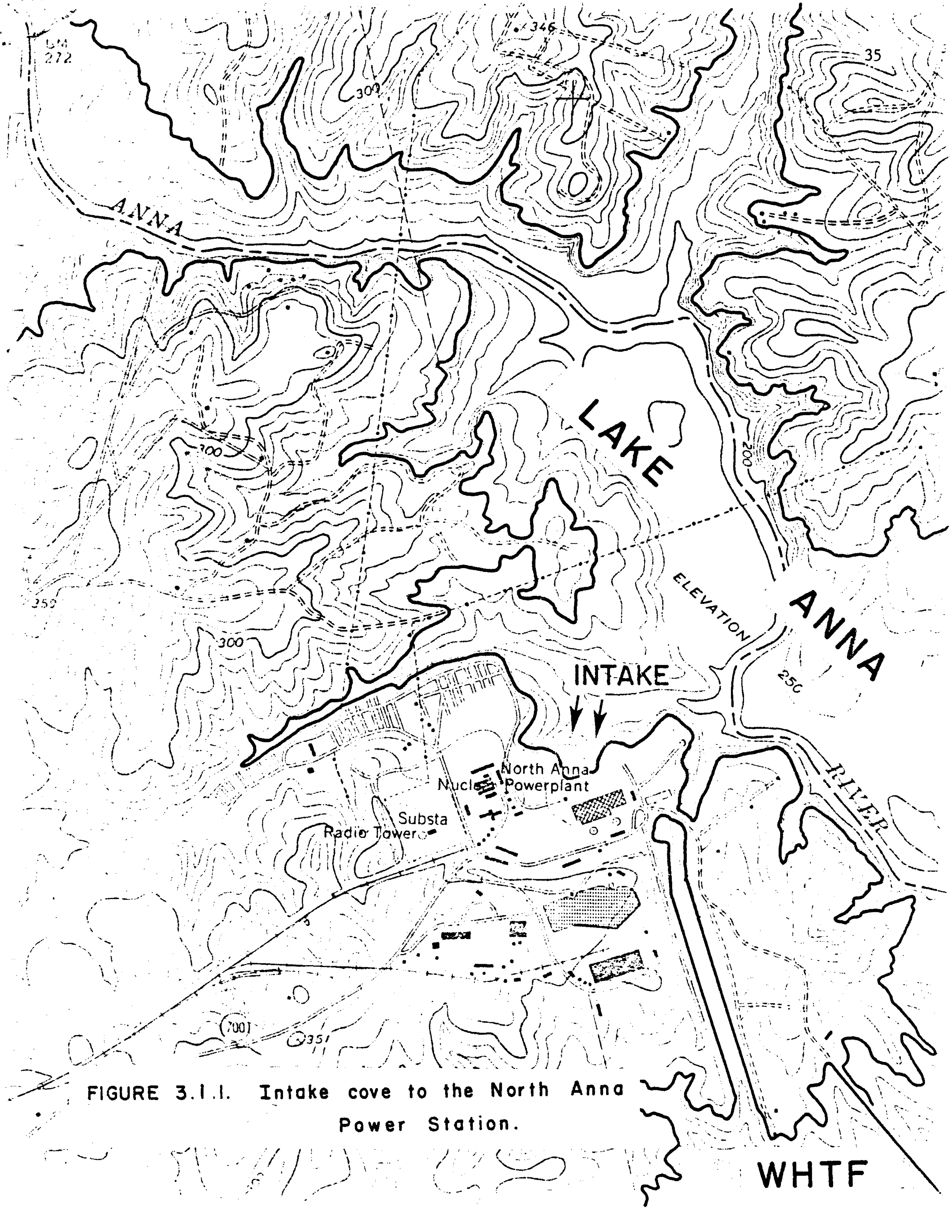


FIGURE 3.1.1. Intake cove to the North Anna Power Station.

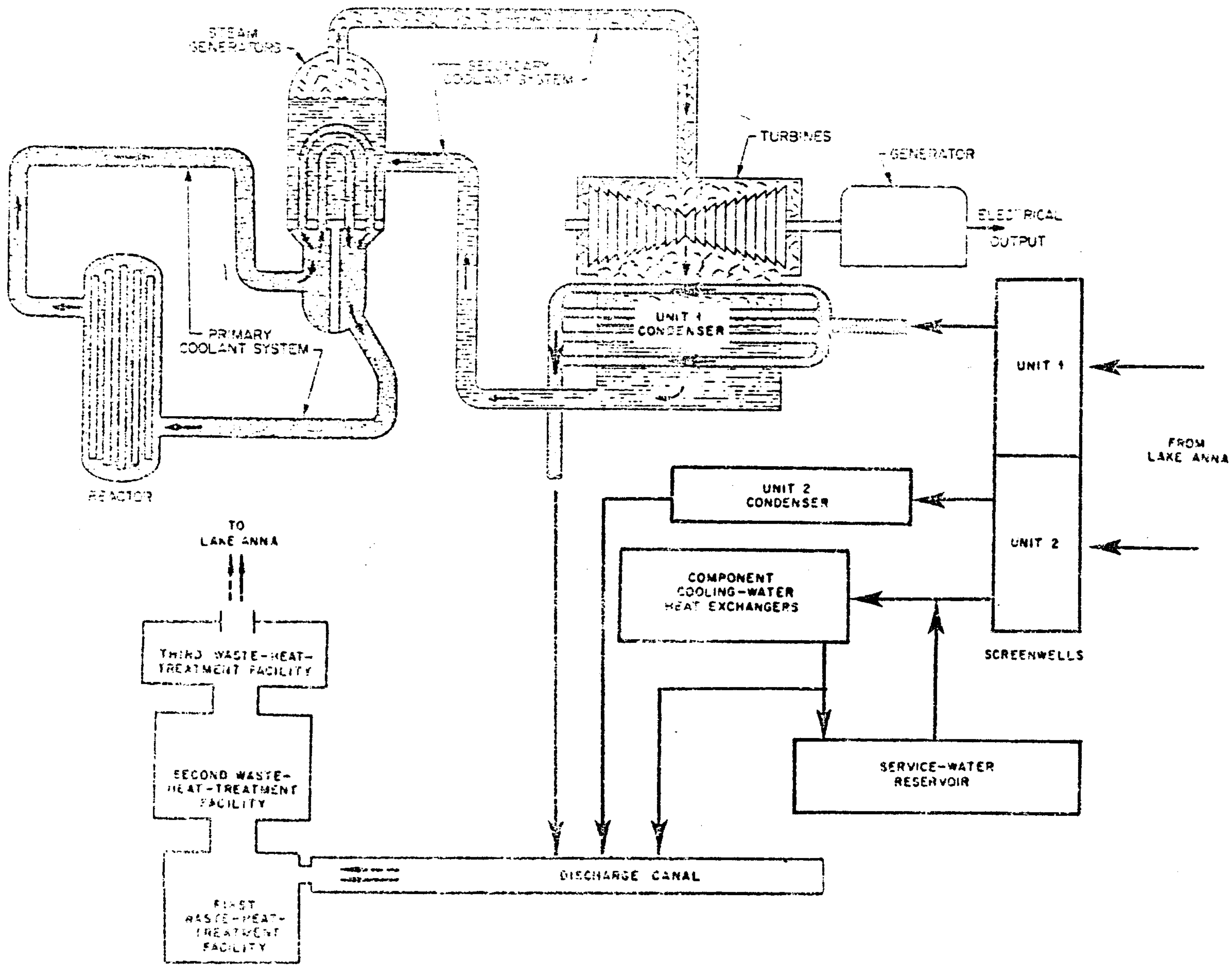


FIGURE 3.2.1. DIAGRAMATIC REPRESENTATION OF THE STEAM-ELECTRIC AND WASTE-HEAT-DISSIPATION SYSTEM FOR THE NORTH ANNA POWER STATION.

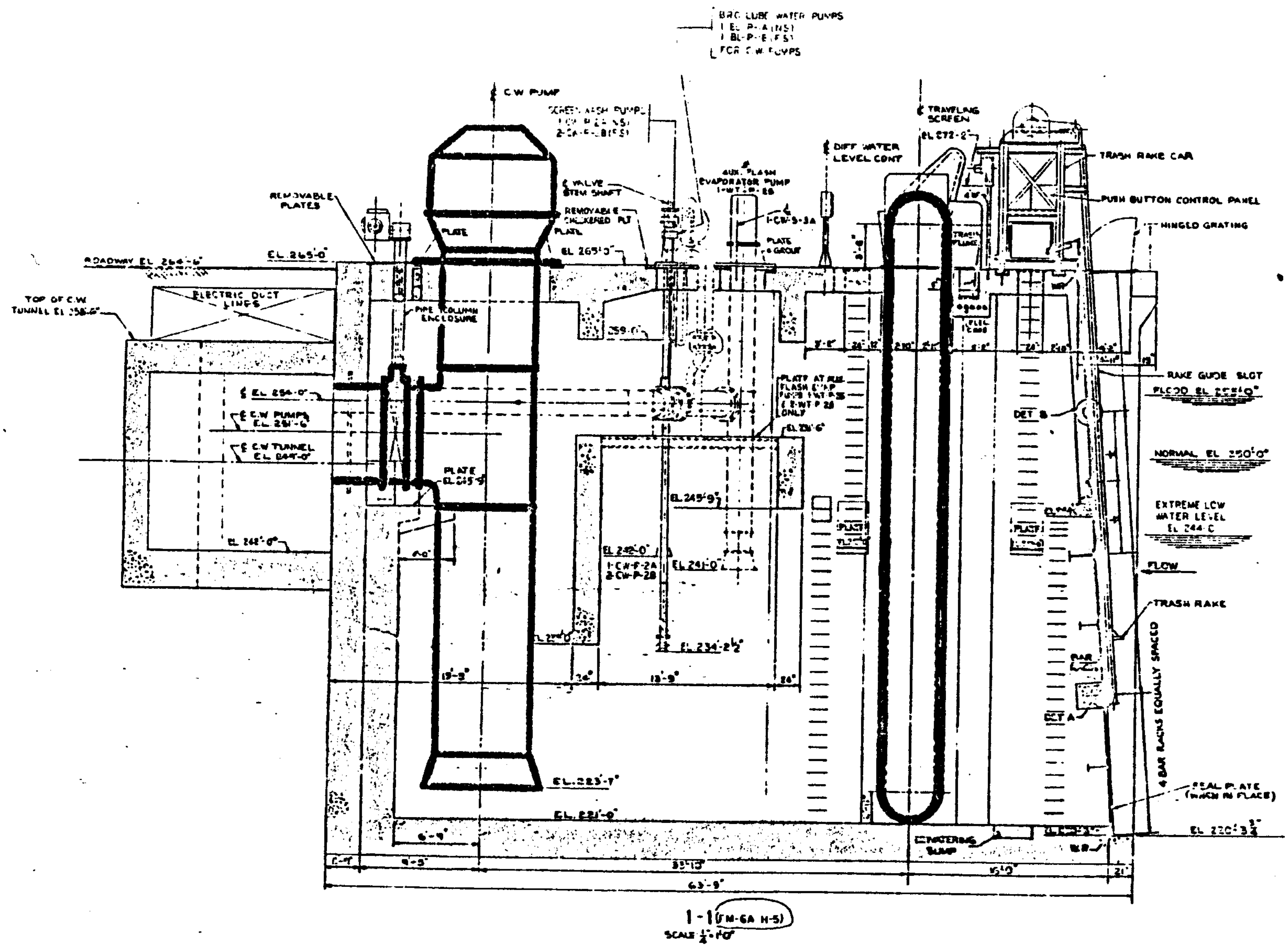


FIGURE 3.3.1. INTAKE BAY WITH TRASH RAKE, TRAVELING SCREEN AND CIRCULATING WATER PUMP.

4.0 OPERATING HISTORY

Lake Anna began receiving thermal additions in April, 1978 when the first nuclear unit became operational. It had been operating commercially for two years, as of June 1978, when Unit 2 was completed in August, 1980. Unit 2 went into commercial operation in December 1980. The daily operations of each unit and the eight circulating water pumps for the study period (1978-1983) are shown graphically in Figures 4.0.1-4.0.10 and summarized by month in Table 4.0.1. These data are combined with air and intake water temperatures to give an overall perspective on station operation (Table 4.0.1, Figures 4.0.1-4.0.10).

Throughout most of 1978, Unit 1 operated near full power (50% capacity). From November through January (1978-1979) all eight pumps were operating. In April of 1979, Unit 1 went off line but then operated near full power until mid-September when it went into an outage. By October of 1980, the station began to approach full operating capacity (both Unit 1 and Unit 2 near full power); the pumps had been running at greater than 80% capacity since June. Power levels and pumps decreased activity during the winter of 1980-1981 (approximating 50% capacity) but geared up again in the spring and early summer of 1981. The level of pumping activity remained high, decreasing in the spring of 1982, but the power level dropped to 50-60% in July, August and October of 1981, and fell off almost completely during the summer of 1982. Power production came up to around 50% capacity in September and by the summer of 1983 both units were operating at near full capacity (from July-September, November and December). Refer back to Figures 2.2.7-2.2.12 for monthly bar graphs of power level and pumping capacities.

TABLE 4.0.1. SUMMARY OF COMBINED POWER LEVELS (%), COMBINED PUMPING CAPACITY (%), AIR TEMPERATURES RECORDED AT BYRD AIRPORT, RICHMOND, VA. (C), AND SURFACE INTAKE WATER TEMPERATURES (C) FOR THE STUDY YEARS, 1978-1983.

YEAR	MONTH	POWER LEVEL	CIRC. WATER PUMPS	AIR TEMP	NALINT
78	1	0.0	5	0.8	3.3
	2	0.0	14	-0.9	3.0
	3	0.0	25	6.9	3.8
	4	6.2	50	14.0	12.5
	5	20.5	44	18.6	18.4
	6	41.5	50	23.7	25.3
	7	42.5	74	25.3	27.7
	8	47.4	52	26.7	28.8
	9	36.0	44	22.7	26.5
	10	42.4	74	14.6	19.6
	11	47.4	85	11.4	15.3
	12	46.6	100	5.8	10.4
79	1	41.4	93	2.4	5.7
	2	43.0	56	-1.9	2.6
	3	44.5	38	10.6	6.6
	4	0.0	34	14.7	13.3
	5	44.0	56	19.5	19.1
	6	48.7	46	21.6	M
	7	47.4	50	24.9	28.2
	8	49.5	50	25.4	27.4
	9	35.1	69	21.7	24.8
	10	0.0	31	14.6	18.6
	11	0.0	25	11.8	13.7
	12	0.0	32	7.4	8.8
80	1	5.0	64	3.8	5.3
	2	38.4	59	2.2	3.6
	3	48.8	58	8.6	6.6
	4	42.7	38	16.2	14.2
	5	35.2	70	20.2	20.3
	6	32.5	82	22.7	24.4
	7	47.4	93	26.7	28.0
	8	50.3	81	27.1	29.1
	9	62.6	92	23.7	27.2
	10	85.4	79	13.8	20.5
	11	47.2	66	7.9	13.5
	12	63.5	71	3.7	8.2

TABLE 4.0.1(CONT). SUMMARY OF COMBINED POWER LEVELS (%), COMBINED PUMPING CAPACITY (%), AIR TEMPERATURES RECORDED AT BYRD AIRPORT, RICHMOND, VA. (C), AND SURFACE INTAKE WATER TEMPERATURES (C) AT ENDECO NALINT FOR THE STUDY YEARS, 1978-1983.

YEAR	MONTH	POWER LEVEL	CIRC. WATER PUMPS	AIR TEMP	NALINT
81	1	42.8	38	-0.4	3.5
	2	48.7	39	5.7	4.6
	3	47.0	44	7.0	7.7
	4	82.0	90	15.9	14.4
	5	79.0	85	17.8	19.8
	6	78.6	84	25.5	26.8
	7	47.4	88	26.4	28.4
	8	59.8	92	23.9	27.5
	9	93.4	100	20.8	25.5
	10	55.6	92	13.6	18.6
	11	94.0	82	9.5	13.7
	12	96.6	75	3.3	9.8
82	1	85.6	75	-0.2	4.1
	2	93.6	75	5.4	5.3
	3	54.6	52	9.5	8.9
	4	43.2	41	13.3	12.9
	5	11.0	38	21.3	21.2
	6	25.0	30	23.0	24.4
	7	9.3	40	25.9	28.9
	8	1.0	38	23.9	27.7
	9	47.2	38	21.0	24.2
	10	49.6	38	15.1	19.1
	11	47.6	64	11.0	13.8
	12	48.3	64	7.8	10.6
83	1	37.5	38	3.2	6.9
	2	47.6	67	3.9	5.4
	3	73.6	75	10.2	8.9
	4	51.6	41	13.4	12.1
	5	42.0	57	18.9	19.3
	6	79.3	92	24.2	25.7
	7	92.2	100	26.3	29.5
	8	99.4	98	25.4	M
	9	95.8	100	20.4	27.2
	10	60.8	92	14.5	21.1
	11	96.6	75	9.4	14.8
	12	96.1	75	2.3	10.1

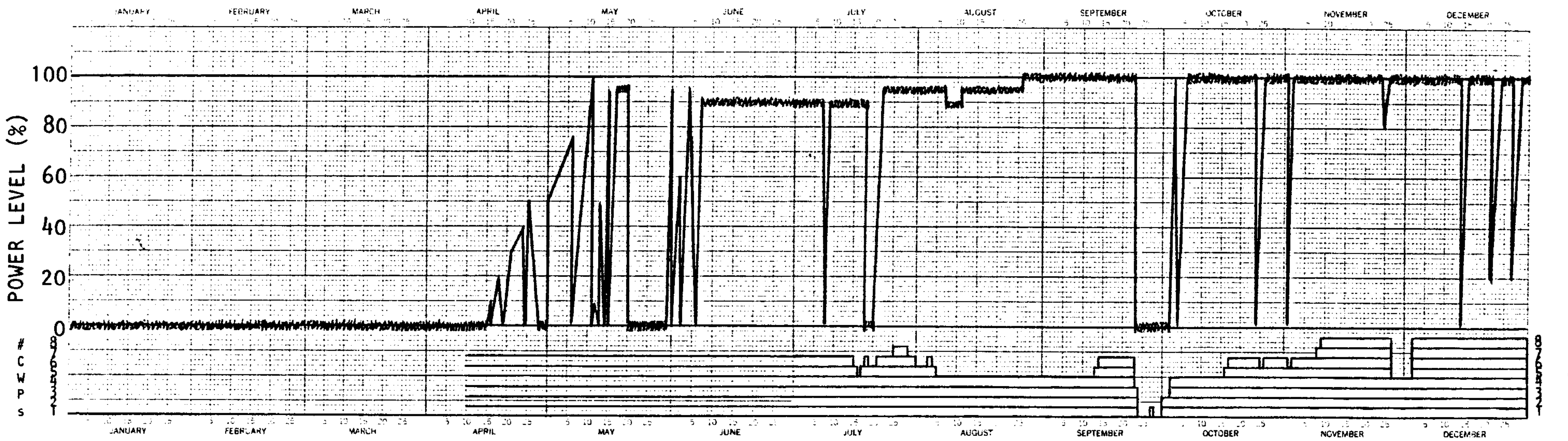


FIGURE 4.0.1. NORTH ANNA UNIT 1 DAILY POWER LEVEL (%) AND CIRCULATING WATER PUMP OPERATION FOR 1978.

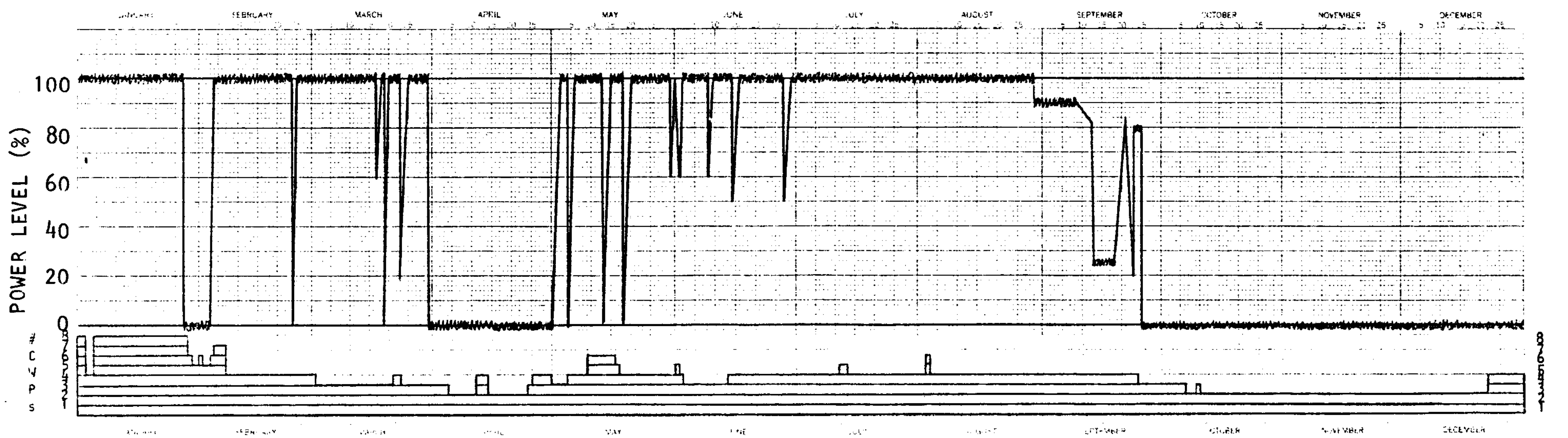


FIGURE 4.0.2. NORTH ANNA UNIT 1 DAILY POWER LEVEL(%) AND CIRCULATING WATER PUMP OPERATION FOR 1979.

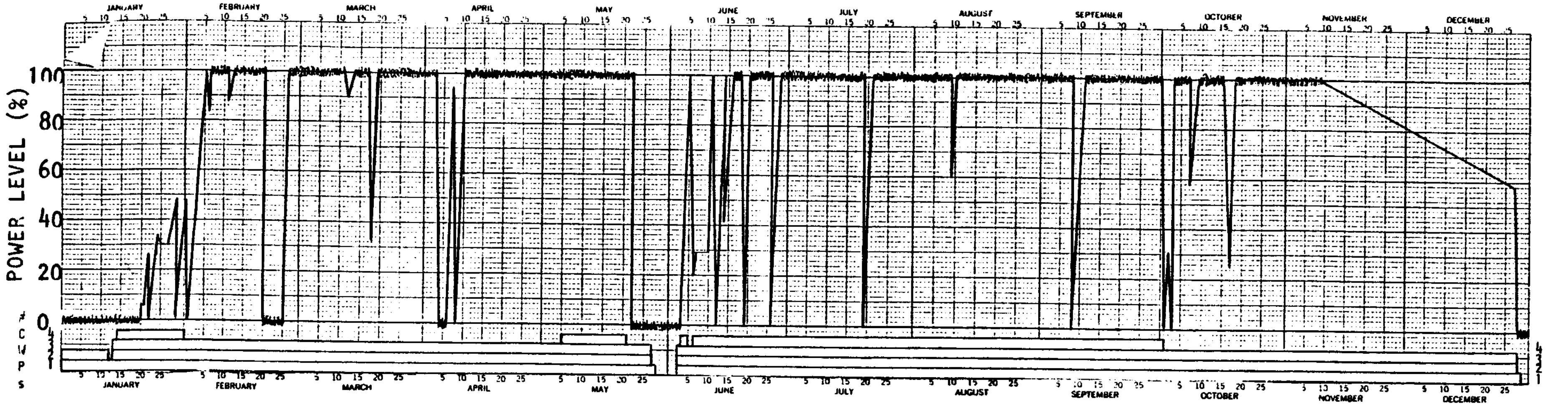


FIGURE 4.0.3. NORTH ANNA UNIT 1 DAILY POWER LEVEL (%) AND CIRCULATING WATER PUMP OPERATION FOR 1980.

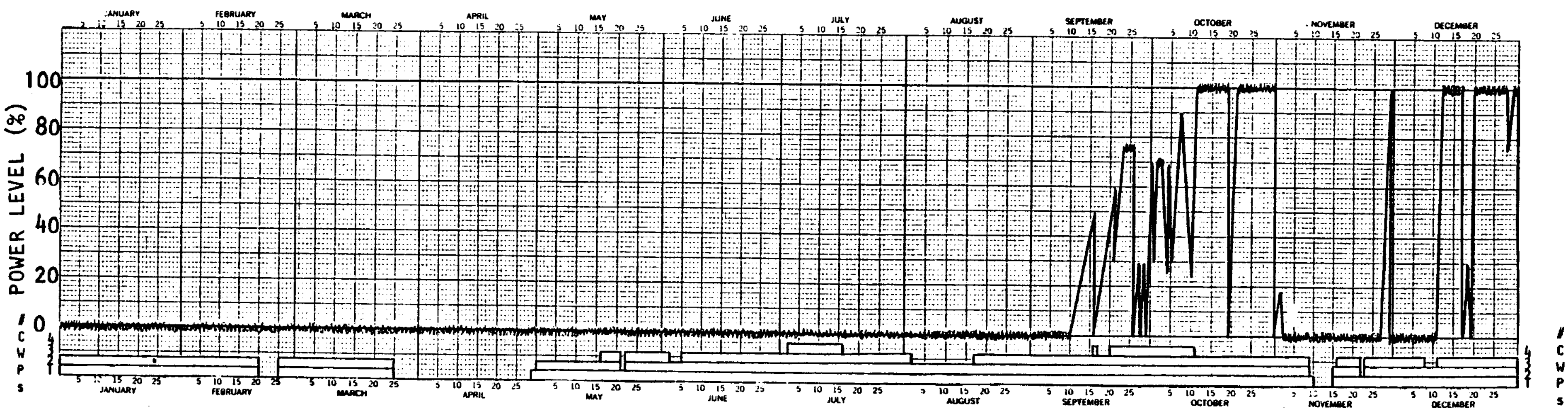


FIGURE 4.0.4. NORTH ANNA UNIT 2 DAILY POWER LEVEL (%) AND CIRCULATING WATER PUMP OPERATION FOR 1980.

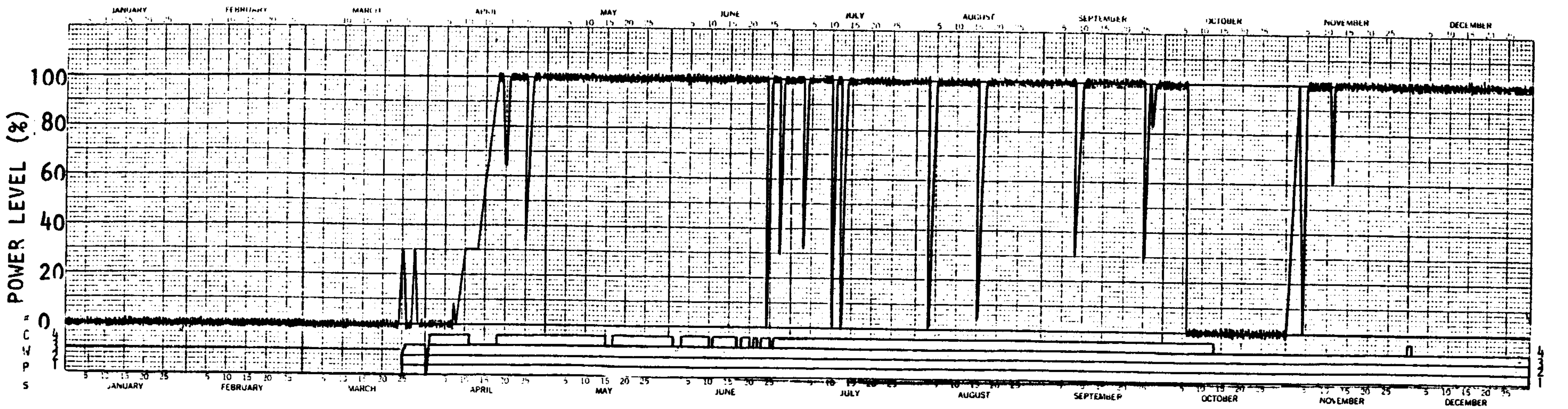


FIGURE 4.0.5 . NORTH ANNA UNIT 1 DAILY POWER LEVEL (%) AND CIRCULATING WATER PUMP OPERATION FOR 1981.

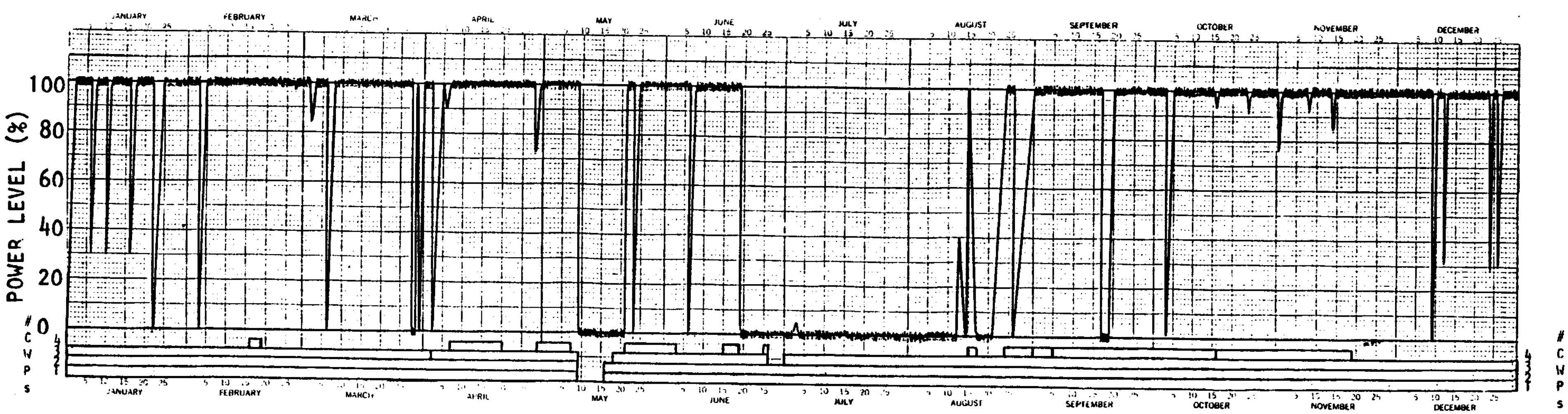


FIGURE 4.0.6 . NORTH ANNA UNIT 2 DAILY POWER LEVEL (%) AND CIRCULATING WATER PUMP OPERATION FOR 1981.

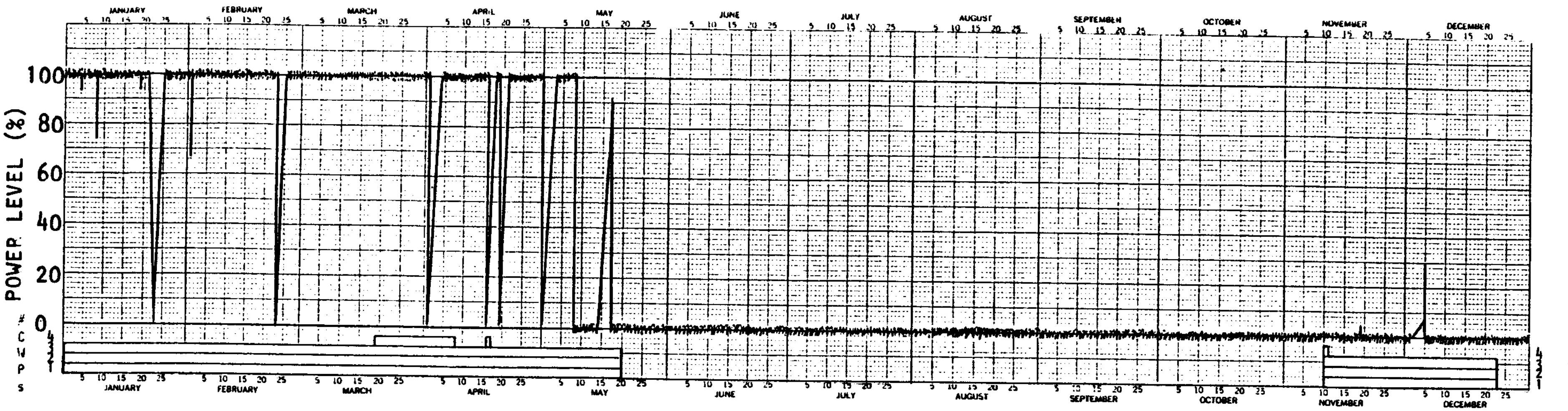


FIGURE 4.0.7 . NORTH ANNA UNIT 1 DAILY POWER LEVEL (%) AND CIRCULATING WATER PUMP OPERATION FOR 1982.

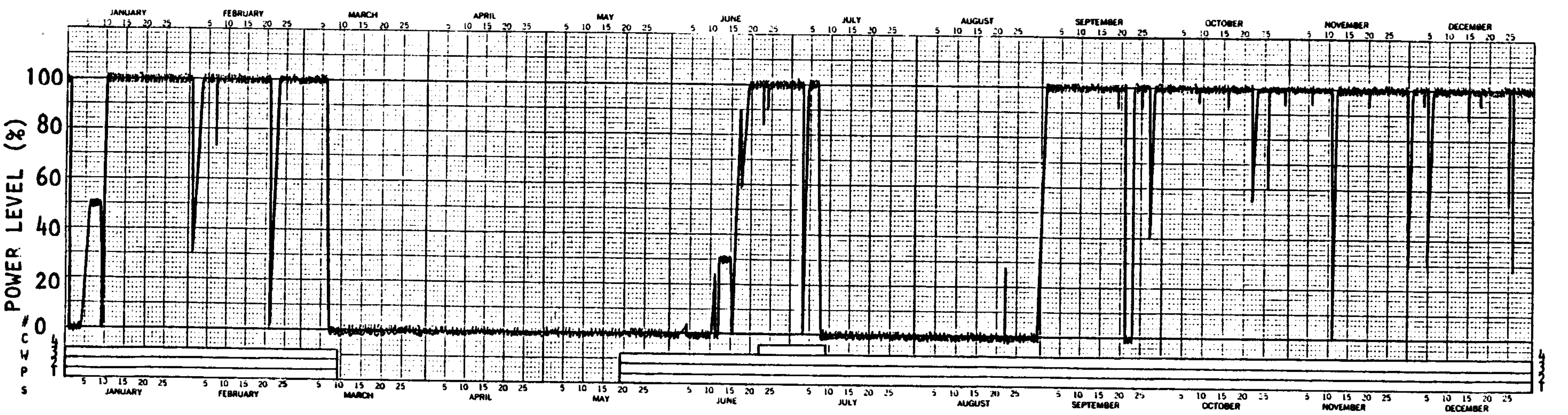


FIGURE 4.0.8 . NORTH ANNA UNIT 2 DAILY POWER LEVEL (%) AND CIRCULATING WATER PUMP OPERATION FOR 1982.

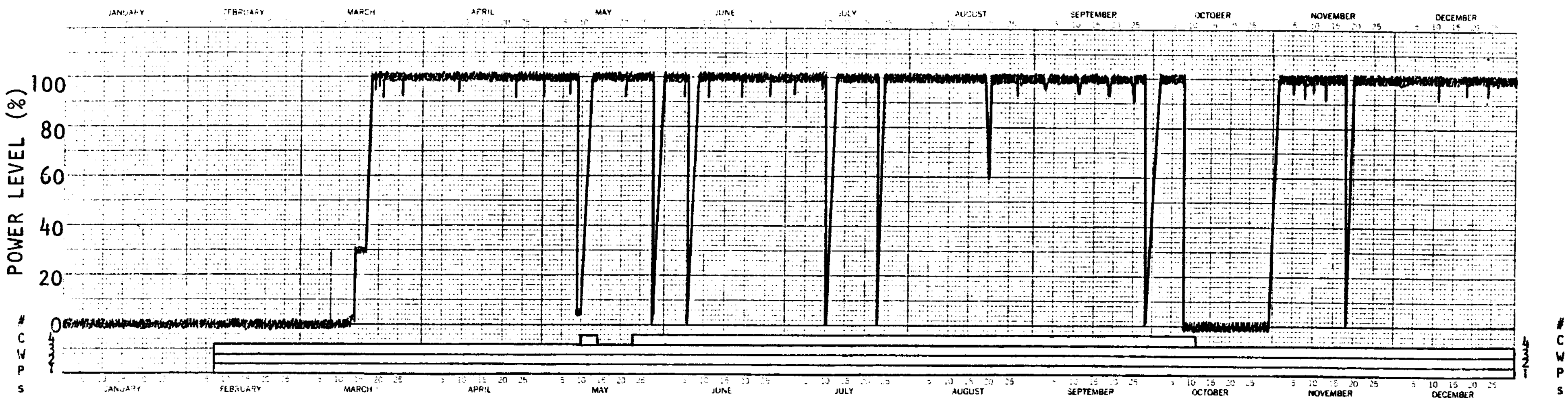


FIGURE 4.0.9. NORTH ANNA UNIT 1 DAILY POWER LEVEL (%) AND CIRCULATING WATER PUMP OPERATION FOR 1983.

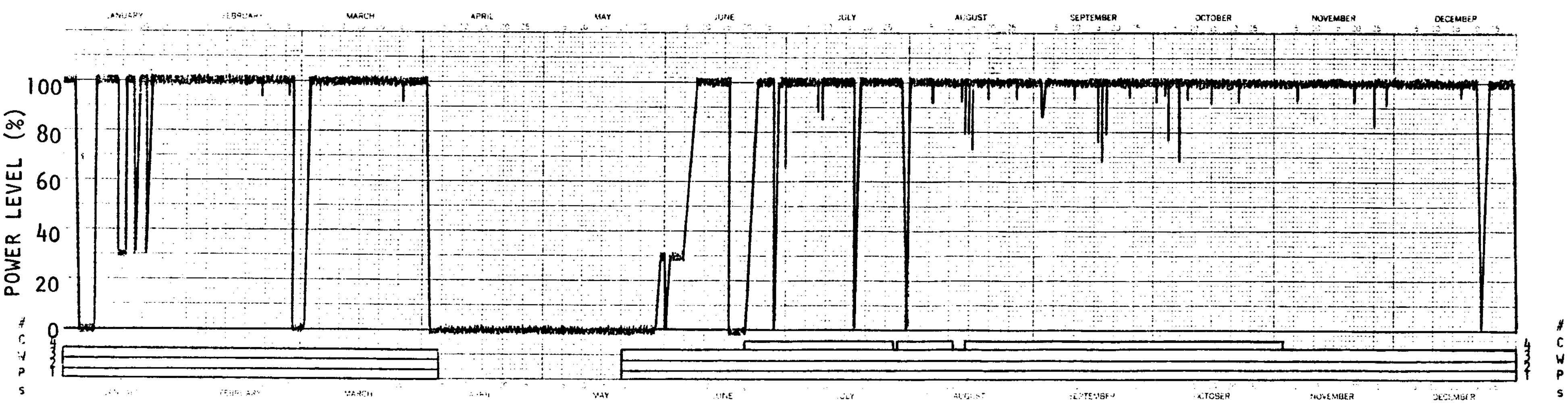


FIGURE 4.0.10. NORTH ANNA UNIT 2 DAILY POWER LEVEL (%) AND CIRCULATING WATER PUMP OPERATION FOR 1983.

5.0 METHODS AND MATERIALS

5.1 Impingement

Impingement, as described in this report, is the collision and subsequent retention of fishes upon the traveling screens of the water intake structure. Impingement samples were collected from April 1978 through December 1983 on a four-week cycle.

The sampling schedule for the first 3 weeks of a 4-week cycle consisted of two 24-hour samples per week collected on non-consecutive days. During the fourth week, a composite sample was taken consisting of twelve continuous 2-hour samples. Screens were washed for 1/2 hour prior to beginning a 24-hour sampling period and the resulting debris and fish remains were disposed of. For each sample collection, environmental laboratory personnel washed each screen for a minimum of 10 minutes to insure all fish were removed. All operable screens were washed when the corresponding circulating water pump was in operation. The fish were washed into a catch basket at the end of a sluiceway and were removed and transported to the laboratory. Decayed fish that obviously had been dead for longer than 24-hours were excluded from the impingement sample. In the laboratory, up to 50 individuals of each species were measured (total length, T.L., in mm) and weighed (nearest 0.1 g). Those species numbering over 50 were enumerated and weighed in bulk. Water temperature, dissolved oxygen, weather conditions and numbers of operating screens and pumps were noted during each sample. All data were recorded on standardized computer data sheets.

Velocity profiles (measured with a Marsh-McBirney Model 201 electromagnetic current meter) were obtained from surface to bottom at one meter intervals in front of the trash racks.

5.2 Entrainment

The 1978-1983 entrainment sampling program extended from March to July of each year. During this period, samples were collected at 0600, 1200, 1800 and 2400 hours each week.

Samples were taken at the surface, mid-depth and bottom by placing paired conical nets in front of a predetermined intake forebay (Figure 5.2.1) for 10 minutes per depth. The mesh size of the netting was .505 μ and the conical measurements were 0.5 m x 1.5 m. After 10 minutes the nets were retrieved and the samples were rinsed into jars. Samples were returned to the laboratory, sorted and preserved in 3% buffered formalin. The collected individuals were identified to the lowest possible taxon. The volume of water filtered during the sample was determined using large-vaned, low-velocity-sensitive digital flowmeters (General Oceanics Model 2030 MK II). Water temperature and dissolved oxygen levels were taken at each sample depth.

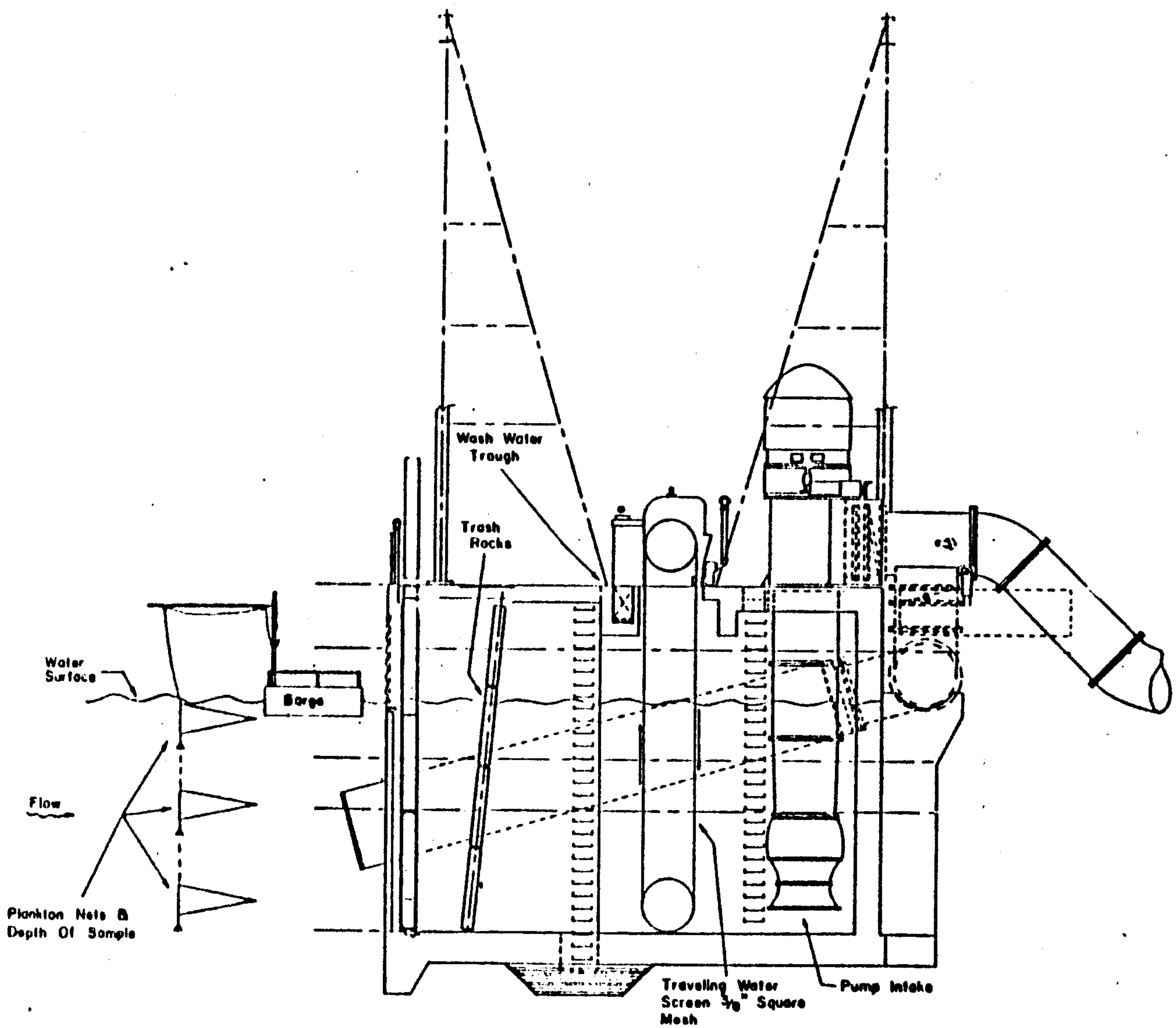


FIGURE 5.2.1. TYPICAL INTAKE STRUCTURE SHOWING ENTRAINMENT SAMPLE LOCATIONS.

6.0 RESULTS AND DISCUSSION

6.1 Impingement

Impingement studies have been conducted at North Anna Power Station for a period of five years and nine months, April 1978 through December 1983. During this time, a total of 2.4×10^5 fishes weighing 5.7×10^3 kg have been impinged, representing 34 species and 13 families (Tables 6.1.1 and 6.1.2). These collection totals extrapolate to an estimated total number of fishes impinged of 9.6×10^5 with an estimated total weight of 2.3×10^4 kg (Table 6.1.3).

The full year having the greatest number of fish impinged was 1979 (61% of total) followed by 1981 (13%); 1980 (12%); 1982 (7%) and 1983 (5%) (Table 6.1.3). During 1978 impingement sampling was not conducted for the entire year. Gizzard shad, Dorosoma cepedianum, comprised 77.6% of the 1979 impingement total, of which 64% (an estimated 2.9×10^5 were impinged between February 20 and March 20 of that year (Tables 6.1.1 and 6.1.2). It is significant, because of the large numbers of fish impinged in 1979, that the lowest water temperature ever recorded (1975-1983) by Endeco temperature monitors in the intake area of Lake Anna was recorded on February 20, 1979 (1.18°C) (Vepco-unpublished data). Low water temperatures will notably reduce gizzard shad mobility (Griffith 1978; McLean et al. 1982). Winter kills (and high winter impingement rates) are common for this species when water temperature falls below 3.3°C (Jester & Jensen 1972), and the higher 1979 impingement rates were most likely influenced by the extreme cold experienced during February of that year.

Seasonally, most fish were impinged during the winter (75% of the total), followed by spring (13%), fall (9%) and summer (3%) (Table 6.1.4). Higher impingement rates during winter and early spring are a common occurrence in other areas (Reutter and Herdendorf 1979; Porak & Tranquilli 1981). Lower water temperatures encountered in winter tend to make fish sluggish so they may not be able to avoid the intake currents as easily (McConnell 1975; Latvaitus 1976).

The estimated total numbers of fish impinged by species by season (winter: January-March; spring: April-June; summer: July-September; fall: October-December) were calculated from the seasonal mean values, which were calculated from daily impingement values. Seasonal estimates were computed by multiplying the number of days in the season by the seasonal daily mean; yearly estimates are the sum of the seasons. To simplify computing, the 24-hour samples and the 12 2-hour samples were combined and both considered 24-hour samples for this report. This is a different formula than used in determining previous impingement estimates so there are slight differences between present estimates and those of previous interim reports.

Water velocities were measured approximately 5m in front of six intake screens under varying modes of operation (Table 3.3.1). The average intake velocity, across all eight bays, with all eight pumps running, was less than 0.21 m/second (0.69 ft/sec). The maximum, at one meter depth in front of bay two was 0.24 m/sec. This is somewhat lower than intake velocities encountered at the Kincaid Generating Station (maximum 0.34 m/sec) in Illinois (Porak and Tranquilli 1981).

Adult fish swimming speeds are related to body morphology and length. Burst speeds of 10 body lengths per second and cruising speeds of 3 body lengths per second are generally accepted for fish (Bainbridge 1958; Blaxter 1969). Burst speeds cannot be sustained for very long and are usually associated with escape responses.

From these data, fish larger than 24 mm total length (.24m/10) should have no trouble escaping the intake screens if they are in good condition and not cold stressed. Impingement length-frequency figures (6.1.1 - 6.1.5) indicate that most impinged fish were larger than 25 mm. This would indicate that fish most vulnerable to entrainment by the power plant are individuals in poor body condition. These are the weaker individuals that would ordinarily be selected by natural predators in the lake.

The most commonly impinged fish during this study was gizzard shad, (61%); followed by black crappie, _Pomoxis nigromaculatus_, (16%); yellow perch _Perca flavescens_, (16%); bluegill _Lepomis macrochirus_, (4%) and white perch _Morone americana_, (1%). No other species comprised more than 1.0% of the total number impinged (Table 6.1.1 and 6.1.3).

Gizzard shad comprised the majority of the fish impinged during 1979 (77.6% of the total); 1981 (51.9%) and 1983 (36.6%). During 1980 and 1982 black crappie were impinged most often (33.1% and 36.9% respectively) (Tables 6.1.1 and 6.1.3).

Gizzard shad is the major forage fish in Lake Anna; however, threadfin shad introduced in 1983 may eventually supplement gizzard shad as the primary forage species. Gizzard shad is an excellent forage fish when small but quickly grows too large for sport fish predation. Adult gizzard shad compete with sport fish for food and habitat (Porak and Tranquilli 1981).

Gizzard shad is the most abundant species in Lake Anna in terms of biomass (kg/ha) (Vepco 1983 and 1984). This species generally frequents open surface waters but is found deeper in fall and early winter (Jones 1978). Adult gizzard shad are large enough to avoid the intake current if healthy, therefore, they were probably already physically impaired in some way when impinged; sluggish from the cold water, possibly dying or already dead and floating or rolling along the bottom. The emaciated condition observed in many of these fish collected in the summer would tend to support this theory. If gizzard shad impinged during the summer are already in poor condition when impinged, as hypothesized above, this should show up in condition value comparisons. Condition values, $K = \frac{W\ 10^5}{L3}$ (Carlander 1969) were calculated for gizzard shad collected from the intake screens during 24-hour samples during October 1983 and compared with a sample of approximately equal length gizzard shad collected from lake gill nets during October 1983. These values (Gill Net-0.83; Impingement-0.60) were found to be significantly different at the 99% level (S.A.S. proc. T-test). October was the only month tested because of the difficulty in obtaining large numbers of equal length gizzard shad.

The length-frequency data for gizzard shad impinged at North Anna between 1978 and 1983 are bimodel with peaks for the 75-125 mmT.L. (48%) and

175-225 mmT.L. (38%) groups (Figure 6.1.2). Cove rotenone data for the years 1981, 1982 and 1983 (the only years length-frequency data is readily available) also indicate low numbers of gizzard shad collected for the 127.0-152.4 mmT.L. size class (4.1, 3.6 and 0.2% respectively) (Vepco 1983 and 1984). Therefore, this gap is probably a cohort growth anomaly rather than an impingement artifact. There was a large gizzard shad year class in 1979 when 92% of the total was less than 150 mmT.L. and the overall gizzard shad total was the highest impinged of all years (Table 6.1.5). The impingement data indicate there was a smaller gizzard shad year class in 1980, very small in 1981 (only 7% less than 150 mmT.L.), building in 1982 and relatively large in 1983 (86% below 150 mmT.L. but smallest total of five year period). Threadfin shad were introduced into Lake Anna in the spring of 1983. Their impingement combined with gizzard shad (6% of total) in 1983 impingement (fall and winter) equals the 1982 impingement total for gizzard shad ($\sim 2.0 \times 10^4$) (Table 6.1.1). Threadfin shad do not grow as large as gizzard shad and are available as forage throughout their life cycle and are therefore considered a better forage species. They are, however, more susceptable to mortalities due to low water temperatures than are gizzard shad (Griffith 1978).

Black crappie was the second most commonly impinged fish over the entire study period and the most commonly impinged during 1980 and 1982 (Table 6.1.1 and 6.1.3). Black crappie is a sought after game fish in Lake Anna but has been declining in number since 1979 when the creel harvest estimate "bottomed out" at 5.7×10^4 compared to the 1978 creel harvest estimate of 1.1×10^5 (Sledd and Shuber 1981).

Cove rotenone studies at Lake Anna have also shown a steady decline of black crappie since 1978 (Vepco 1983 and 1984). Although cove rotenone studies have sometimes proven inadequate as a basis for estimating black crappie standing crops in reservoirs (Carter 1958), the Lake Barkley rotenone study (Aggus et al. 1979) found that black crappie recovery from small coves did approximate their total standing crop. Black crappie feed primarily on minnows but also on aquatic insects and other organisms (Hildebrand and Schroeder 1928; Eddy and Underhill 1943) and would be attracted to the intakes by the volume of planktonic food organisms, and the smaller fishes which feed on them, flowing through the system. Black crappie are also attracted to structure in deeper water (Pflieger 1975) and so might also be attracted to the intake structure for this reason. The decline in the population over the study period may be partly due to the lack of structure in the lake, as the lake was completely clear-cut prior to impoundment. Black crappie prefer to spawn in or near underwater structure, and the lack of structure in the lake may limit its spawning success.

More than 60% of the black crappie impinged during the five plus year study were larger than 150 mmT.L. (Figure 6.1.1). This is similar to cove rotenone data for the years 1981, 1982 and 1983 when 52%, 75% and 60% respectively of the black crappie collected were larger than 150 mmT.L. (Vepco 1983 and 1984). The percentage of small crappie ($<$ 100 mmT.L.) impinged has decreased dramatically since 1978; from 32% of total crappie impinged in 1978 to 1% in 1982 and 1983 (Table 6.1.6). This is symptomatic of a relative decline in population.

Yellow perch was the third most frequently impinged species, during the study, at 16% of the total (Table 6.1.1). Estimated impingement declined during this period from a high of 8.7×10^4 in 1979 to a low of 3.5×10^3 in 1983 and averaged 2.9×10^4 Yellow perch is a sought after game species by anglers in the Northern states (Ney 1978); however, it is insignificant as a sport fish in the South (Clugston et al. 1978). It's primary importance in Lake Anna is as a forage fish. During the 1976-1979 North Anna creel surveys, yellow perch was listed as a non-game species, however, an estimated yearly average of 1,828 were creeled during that period (Sledd and Shuber 1981). During the 1983 creel survey, the estimated total number of creeled yellow perch was only 107, or 0.3% of the total fish caught.

North Anna cove rotenone data also indicate that the standing crop of yellow perch has been declining in the lake since 1976, from 17.98 kg/ha to 4.22 kg/ha in 1983 (Vepco 1983 and 1984). Rotenone samples in Keowee Reservoir and Jocasse Reservoir in South Carolina indicated much lower yellow perch standing crops than North Anna, ranging from 0.1 to 2.2 kg/ha (Clugston et al. 1981). As Lake Anna cove rotenone samples were collected in August in generally shallow areas, it is quite possible that the standing crop of yellow perch is underestimated as they may have been concentrated in the deeper, cooler water at this time. Yellow perch generally prefer cooler water (18-21°C for adults and 20-24°C for juveniles) (Ferguson 1958; McCauly and Read 1973). Relative changes in yellow perch standing crop determined from cove rotenone data probably reflect actual population changes. This agrees with the declines noted in impingement and creel survey data.

Yellow perch feed primarily on small crustaceans, insects and fish spending the day in deep water while moving inshore to feed in the evening (Pflieger 1975). Therefore, their presence in front of the screens is not unexpected for the same reasons as those given for black crappie.

Most of the yellow perch (92%) impinged during this study were smaller than 150 mm in length (Figure 6.1.3). This compares favorably with lake population studies (rotenone) which indicates that most of the yellow perch population is from year class 0 to year class II (0-150 mmT.L.); during 1981, 97.3% of the yellow perch collected were less than 150 mm; 1982, 99.3% and 1983, 92.6% (Vepco 1983 and 1984). The number of small yellow perch (< 100 mmT.L.) impinged has decreased yearly from 1978 through 1981 and then increased slightly in 1982 and 1983 (Table 6.1.7). This might indicate a leveling off of the yellow perch population decline.

Bluegill was the fourth most often impinged fish during the five plus year study period at 4% of the total and an annual average impingement rate of 7.5×10^3 (Table 6.1.1 and 6.1.2). Bluegill impingement increased in 1980 and again in 1981 then decreased considerably during 1982, with a slight increase during 1983 (Table 6.1.3). Bluegill is the numerically dominant species in Lake Anna (Vepco 1983 and 1984) and is considered a game fish in the lake (Sledd and Shuber 1981). It is also one of the primary forage fishes in the lake, at small sizes (determined from laboratory game fish stomach analysis) (Vepco 1983).

Annual cove rotenone data indicate a fairly steady standing crop of bluegill in the lake since 1979, that ranges from 58.8 kg/ha to 74.2 kg/ha with an average of 65.3 kg/ha. Although bluegill feed on the same general food items as black crappie and yellow perch, they prefer to forage in weed beds in shallow areas (Eddy and Underhill 1943). Their presence in impingement samples is therefore probably more related to their numerical dominance in the lake than to their preferred habitat.

The majority of the bluegill (73%) impinged during this study were small (< 100 mmT.L.) (Figure 6.1.4). This concurs with rotenone data for 1981, 1982 and 1983 when fish in the bluegill population less than 101.6 mmT.L. was estimated at 88%, 78% and 89% respectively (Vepco 1983 and 1984). It appears from these data that a slightly greater percentage of larger bluegill was impinged than exist in the population as a whole. This may be because larger bluegill are attracted to the intake area to feed, especially in the spring, when schools of them can be seen feeding on the surface in front of the intakes, presumably on fish larvae and insects.

Small bluegill (< 100 mmT.L.) as a percentage of total bluegill impinged annually has increased steadily, from 30% in 1978 to 70% in 1983 (Table 6.1.8). The estimated total number impinged has also increased annually (Table 6.1.3) indicating a thriving bluegill population in the lake. This is supported by the previously mentioned rotenone data.

White perch was the fifth most often impinged fish during the five plus year study period, and the last species comprising more than 1% of the total (Table 6.1.1). This species comprised 1.4% of the total number impinged with an estimated annual average of 2.7 x 10^3 (Table 6.1.1 and 6.1.3). White perch impingement generally increased over the study period, matching the increase of white perch in the lake. White perch were first documented in the Lake in 1973 and were not collected again until 1976. Since 1976, the white perch population has increased dramatically in Lake Anna according to results of ongoing adult fish and ichthyoplankton survey programs (Cooke 1984). Since 1977, the increase in white perch population has been accompanied by a decrease in the black crappie population. Black crappie comprised 15.0% of the reservoir standing crop in 1976 and white perch 0.02% (from rotenone data). By 1983, black crappie comprised 1.5% and white perch 8.2% of the total standing crop (Vepco 1983 and 1984). This exchange of relative dominance is probably not directly related to white perch, as the major decreases in the size of the crappie population occurred during 1976 and 1977 when white perch still comprised an insignificant portion of the standing crop.

White perch was considered a non-game species during the 1976-1979 creel survey when a annual estimated average of 86 fish were creeled (Sledd and Shuber 1981). During the 1984 survey an estimated 2.6 x 10^3 (6.8% of the total) white perch were creeled. Currently, its main contribution to the Lake Anna fishery, however, is as a forage fish at small sizes (Vepco 1983). White perch is a sought after game fish in estuarine and tidal fresh waters, but usually becomes stunted and a "rough" fish in impoundments. (Hildebrand and Schroeder 1928; Mansueti 1964; Hergenrader and Bliss 1971; Wallace 1971; St. Pierre and Davis 1972).

White perch feeds primarily on small fish (Hildebrand and Schroeder 1928) as do black crappie and yellow perch. Being primarily an open water species its presence in impingement samples is not unexpected. As the total number of white perch increased annually in impingement samples, the percent of small fish (< 200 mmT.L.) also increased. This is indicative of an expanding population; however, combined with a relative lack of larger individuals, this change may also indicate a stunting of the population (Table 6.1.9). These data are similar to rotenone data (Vepco 1983 and 1984).

The majority of the remaining species (68% of the total) collected were small, less than 150 mmT.L. (Figure 6.1.5). This is probably a reflection of the total lake standing crop, comprised of mostly smaller, younger individuals.

Generally, new reservoirs show a trend of high initial productivity followed by decline. This is primarily due to high nutrient levels from freshly inundated vegetation and soil. Environmental conditions tend to stabilize 5 to 10 years after impoundment and fish biomass stabilization follows (Jenkins 1977). Lake Anna exhibited high initial fish abundance during 1973 and 1974 followed by a decline in 1975 (Reed and Simmons 1976, Appendix A). During 1976, the Lake Anna mean standing crop was 295.9 kg/ha (from cove rotenone data). The most productive area (at least in future samples), Pamunkey Creek Arm, was not sampled that year. During 1977, with all four coves sampled, the mean standing crop was 332.0 kg/ha, which decreased during 1978 to 262.4 kg/ha. Since 1978, the mean standing crop has fluctuated but averaged 267.8 kg/ha for the following 5-year period.

Year	Lake Mean Standing Crop (kg/ha)
1976	295.9
1977	332.0
1978	262.4
1979	233.1
1980	321.1
1981	263.3
1982	265.8
1983	257.3

These data would appear to indicate a stabilization of standing crop, as predicted by Jenkins (1977), which has been unaffected by impingement rates.

TABLE 6.1.1. THE TOTAL CATCH, PER CENT AND ESTIMATED CATCH OF FISHES IMPINGED AT NORTH ANNA POWER STATION, 1978-1983

FAMILY	SPECIES	COMMON NAME	1978 CATCH	1978 PERCENT	1978 ESTIMATE	1979 CATCH	1979 PERCENT	1979 ESTIMATE
ANGUILLIDAE	ANGUILLA ROSTRATA	American eel	1	0.0	4.00	62	0.0	243
APHREDODERIDAE	APHREDODERUS SAYANUS	pirate perch	.	.	.	.	.	.
CATOSTOMIDAE	CATOSTOMUS COMMERSONI	white sucker	.	.	.	.	.	.
	ERIMYZON OBLONGUS	creek chubsucker	1	0.0	4.33	.	.	.
CENTRARCHIDAE	ACANTHARCHUS POMOTIS	mud sunfish	.	.	.	7	0.0	28
	LEPOMIS AURITUS	redbreast sunfish	2	0.0	8.71	1	0.0	4
	LEPOMIS GIBBOSUS	pumpkinseed	4	0.1	17.43	11	0.0	43
	LEPOMIS GULOSUS	warmouth	4	0.1	17.33	9	0.0	35
	LEPOMIS MACROCHIRUS	bluegill	163	3.1	705.33	626	0.4	2463
	LEPOMIS MICROLOPHUS	redear sunfish	.	.	.	2	0.0	8
	MICROPTERUS SALMOIDES	largemouth bass	36	0.7	153.05	8	0.0	31
	POMOXIS NIGROMACULATUS	black crappie	2194	42.0	9121.05	9750	6.5	38349
CLUPEIDAE	ALOSA AESTIVALIS	blueback herring	.	.	.	.	.	.
	DOROSOMA CEPEDIANUM	gizzard shad	777	14.9	3276.95	115691	77.6	452950
	DOROSOMA PETENENSE	threadfin shad	.	.	.	.	.	.
CYPRINIDAE	EXOGLOSSUM MAXILLINGUA	cutlips minnow	.	.	.	.	.	.
	NOTEMIGONUS CRYSOLEUCAS	golden shiner	9	0.2	38.33	21	0.0	83
	NOTROPIS ANALOSTANUS	satinfin shiner	1	0.0	4.33	.	.	.
	NOTROPIS CORNUTUS	common shiner	.	.	.	.	.	.
	PHOXINUS OREAS	mountain redbelly dace	.	.	.	1	0.0	4
	PIMEPHALES NOTATUS	bluntnose minnow	.	.	.	.	.	.
CYPRINODONTIDAE	FUNDULUS HETEROCLITUS	mummichog	.	.	.	.	.	.
ESOCIDAE	ESOX NIGER	chain pickerel	.	.	.	.	.	.
ICTALURIDAE	ICTALURUS CATUS	white catfish	.	.	.	.	.	.
	ICTALURUS NATALIS	yellow bullhead	3	0.1	13.00	.	.	.
	ICTALURUS NEBULOSUS	brown bullhead	155	3.0	673.33	160	0.1	629
	ICTALURUS PUNCTATUS	channel catfish	2	0.0	8.71	5	0.0	20
PERCICHTHYIDAE	MORONE AMERICANA	white perch	8	0.2	34.62	311	0.2	1220
	MORONE SAXATILIS	striped bass	37	0.7	151.00	253	0.2	1003
PERCIDAE	ETHEOSTOMA OLMSTEDI	tessellated darter	.	.	.	.	.	.
	PERCA FLAVESCENS	yellow perch	1821	34.9	7890.81	22070	14.8	86389
	STIZOSTEDION VITREUM	walleye	.	.	.	.	.	.
PETROMYZONTIDAE	PETROMYZON MARINUS	sea lamprey	.	.	.	7	0.0	28
UMBRIDAE	UMBRA PYGMAEA	eastern mudminnow	.	.	.	.	.	.

TABLE 6.1.1(CONT). THE TOTAL CATCH, PER CENT AND ESTIMATED CATCH OF FISHES IMPINGED AT NORTH ANNA POWER STATION, 1978-1983

FAMILY	SPECIES	1980 CATCH	1980 PERCENT	1980 ESTIMATE	1981 CATCH	1981 PERCENT	1981 ESTIMATE
ANGUILLIDAE	ANGUILLA ROSTRATA	6	0.0	23.5	3	0.0	12.1
APHREDODERIDAE	APHREDODERUS SAYANUS	.	.	.	.	.	.
CATOSTOMIDAE	CATOSTOMUS COMMERSONI	.	.	.	.	.	.
	ERIMYZON OBLONGUS	.	.	.	.	.	.
CENTRARCHIDAE	ACANTHARCHUS POMOTIS	6	0.0	24.1	3	0.0	12.0
	LEPOMIS AURITUS	12	0.0	46.6	5	0.0	19.9
	LEPOMIS GIBBOSUS	31	0.1	119.2	12	0.0	48.0
	LEPOMIS GULOSUS	9	0.0	35.6	12	0.0	47.6
	LEPOMIS MACROCHIRUS	2460	8.7	9638.2	3839	12.1	15321.0
	LEPOMIS MICROLOPHUS	.	.	.	1	0.0	4.0
	MICROPTERUS SALMOIDES	30	0.1	117.6	14	0.0	56.0
	POMOXIS NIGROMACULATUS	9361	33.1	36773.9	7733	24.3	31154.6
CLUPEIDAE	ALOSA AESTIVALIS	5	0.0	19.2	14	0.0	56.0
	DOROSOMA CEPEDIANUM	6808	24.1	27031.0	16474	51.9	66491.6
	DOROSOMA PETENENSE	.	.	.	.	.	.
CYPRINIDAE	EXOGLOSSUM MAXILLINGUA	.	.	.	1	0.0	4.0
	NOTEMIGONUS CRYSOLEUCAS	16	0.1	63.5	24	0.1	96.4
	NOTROPIS ANALOSTANUS	.	.	.	3	0.0	12.0
	NOTROPIS CORNUTUS	.	.	.	1	0.0	4.0
	PHOXINUS OREAS	.	.	.	.	.	.
	PIMEPHALES NOTATUS	.	.	.	2	0.0	8.2
CYPRINODONTIDAE	FUNDULUS HETEROCLITUS	.	.	.	.	.	.
ESOCIDAE	ESOX NIGER	1	0.0	3.9	1	0.0	4.1
ICTALURIDAE	ICTALURUS CATUS	.	.	.	.	.	.
	ICTALURUS NATALIS	1	0.0	4.1	.	.	.
	ICTALURUS NEBULOSUS	46	0.2	186.0	87	0.3	346.1
	ICTALURUS PUNCTATUS	7	0.0	27.2	3	0.0	12.1
PERCICHTHYIDAE	MORONE AMERICANA	174	0.6	679.9	613	1.9	2445.9
	MORONE SAXATILIS	739	2.6	2846.9	1110	3.5	4482.5
PERCIDAE	ETHEOSTOMA OLMSTEDI	1	0.0	3.9	1	0.0	4.0
	PERCA FLAVESCENS	8573	30.3	33674.7	1812	5.7	7385.4
	STIZOSTEDION VITREUM	.	.	.	.	.	.
PETROMYZONTIDAE	PETROMYZON MARINUS	1	0.0	3.9	.	.	.
UMBRIDAE	UMBRA PYGMAEA	.	.	.	.	.	.

TABLE 6.1.1(CONT). THE TOTAL CATCH, PER CENT AND ESTIMATED CATCH OF FISHES IMPINGED AT NORTH ANNA POWER STATION, 1978-1983

FAMILY	SPECIES	1982 CATCH	1982 PERCENT	1982 ESTIMATE	1983 CATCH	1983 PERCENT	1983 ESTIMATE	TOTAL ESTIMATE	TOTAL PERCENT	TOTAL CATCH
ANGUILLIDAE	ANGUILLA ROSTRATA	8	0.0	31.3	2	0.0	7.8	321	0.0	82
APHREDODERIDAE	APHREDODERUS SAYANUS	.	.	.	1	0.0	4.0	4	0.0	1
CATOSTOMIDAE	CATOSTOMUS COMMERSONI	1	0.0	4.0	.	.	.	4	0.0	1
	ERIMYZON OBLONGUS	1	0.0	4.0	.	.	.	8	0.0	2
CENTRARCHIDAE	ACANTHARCHUS POMOTIS	1	0.0	4.0	4	0.0	15.8	84	0.0	21
	LEPOMIS AURITUS	1	0.0	3.9	11	0.1	44.7	128	0.0	32
	LEPOMIS GIBBOSUS	14	0.1	55.3	1	0.0	4.4	288	0.0	73
	LEPOMIS GULOSUS	4	0.0	15.8	15	0.1	60.3	212	0.0	53
	LEPOMIS MACROCHIRUS	1012	6.0	4011.8	1404	12.7	5753.7	37893	3.9	9504
	LEPOMIS MICROLOPHUS	2	0.0	7.8	4	0.0	15.8	35	0.0	9
	MICROPTERUS SALMOIDES	7	0.0	28.0	14	0.1	56.3	442	0.0	109
	POMOXIS NIGROMACULATUS	6260	36.9	24593.8	2756	24.9	11018.0	151011	15.7	38054
CLUPEIDAE	ALOSA AESTIVALIS	4	0.0	15.7	27	0.2	117.1	208	0.0	50
	DOROSOMA CEPEDIANUM	5000	29.5	19594.7	4050	36.6	17164.1	586508	61.4	148800
	DOROSOMA PETENENSE	.	.	.	640	5.8	2794.6	2795	0.3	640
CYPRINIDAE	EXOGLOSSUM MAXILLINGUA	.	.	.	.	.	.	4	0.0	1
	NOTEMIGONUS CRYSOLEUCAS	19	0.1	76.3	31	0.3	123.4	481	0.0	120
	NOTROPIS ANALOSTANUS	1	0.0	4.0	.	.	.	20	0.0	5
	NOTROPIS CORNUTUS	1	0.0	4.0	.	.	.	8	0.0	2
	PHOXINUS OREAS	.	.	.	.	.	.	4	0.0	1
	PIMEPHALES NOTATUS	.	.	.	.	.	.	8	0.0	2
CYPRINODONTIDAE	FUNDULUS HETEROCLITUS	.	.	.	3	0.0	11.8	12	0.0	3
ESOCIDAE	ESOX NIGER	.	.	.	3	0.0	11.8	20	0.0	5
ICTALURIDAE	ICTALURUS CATUS	1	0.0	4.0	.	.	.	4	0.0	1
	ICTALURUS NATALIS	.	.	.	.	.	.	17	0.0	4
	ICTALURUS NEBULOSUS	45	0.3	178.8	19	0.2	75.1	2088	0.2	512
	ICTALURUS PUNCTATUS	6	0.0	23.7	10	0.1	39.7	131	0.0	33
PERCICHTHYIDAE	MORONE AMERICANA	1312	7.7	5168.3	1003	9.1	4081.1	13630	1.4	3421
	MORONE SAXATILIS	237	1.4	938.6	153	1.4	601.3	10023	1.0	2529
PERCIDAE	ETHEOSTOMA OLMSTEDI	.	.	.	.	.	.	8	0.0	2
	PERCA FLAVESCENS	3008	17.8	11778.1	910	8.2	3582.1	150700	15.8	38194
	STIZOSTEDION VITREUM	1	0.0	3.9	1	0.0	4.0	8	0.0	2
PETROMYZONTIDAE	PETROMYZON MARINUS	.	.	.	.	.	.	31	0.0	8
UMBRIDAE	UMBRA PYGMAEA	.	.	.	1	0.0	3.9	4	0.0	1

TABLE 6.1.2. THE NUMBER AND WEIGHT (GMS.) OF INDIVIDUALS FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED AT NORTH ANNA POWER STATION BY SAMPLE DATE, 1978- 1983. VALUES REPRESENT TOTALS OVER A 24-HOUR PERIOD. ABBREVIATIONS ARE: DC - DOROSOMA CEPEDIANUM, PN - POMOXIS NIGROMACULATUS, PF - PERCA FLAVESCNS, LMA -LEPOMIS MACROCHIRUS, MA - MORONE AMERICANA, OT - OTHER. THE SUFFIXES ARE T - NUMBER AND W - WEIGHT.

DATE	DCT	DCW	PNT	PNW	PFT	PFW	LMAT	LMAW	MAT	MAW	OTT	OTW	TFISH	TWT
780411	156	3999.7	98	2893.0	1468	8160.3	3	164.6	0	0.0	11	571.3	1736	15788.9
780413	52	1271.5	49	1607.0	93	899.8	3	205.5	0	0.0	5	44.0	202	4027.8
780418	18	581.4	18	823.7	17	400.7	1	130.4	0	0.0	2	105.7	56	2041.9
780420	23	621.1	12	529.5	9	96.2	5	301.8	0	0.0	0	0.0	49	1548.6
780425	35	954.3	10	235.7	15	126.3	3	224.5	0	0.0	3	129.8	66	1670.6
780427	55	1465.6	25	548.9	15	180.0	3	180.6	0	0.0	4	220.1	102	2595.2
780502	11	507.6	22	613.2	18	400.5	4	152.2	0	0.0	4	32.5	59	1706.0
780509	13	529.6	27	997.0	130	907.6	8	403.0	0	0.0	1	78.1	179	2915.3
780511	15	627.1	33	1097.7	11	152.6	2	13.0	0	0.0	7	594.2	68	2484.6
780516	7	272.1	65	2760.4	5	106.9	3	44.9	0	0.0	15	1679.5	95	4863.8
780518	15	685.2	60	3562.1	2	41.6	7	349.0	0	0.0	7	784.7	91	5422.6
780523	6	234.7	112	6719.3	12	265.0	2	182.1	0	0.0	12	1305.5	144	8706.6
780525	2	136.1	58	3266.0	3	102.3	4	151.9	0	0.0	4	372.0	71	4028.3
780601	2	99.1	61	2691.3	9	64.3	4	274.8	0	0.0	17	2178.1	93	5307.6
780606	3	130.0	20	817.2	2	214.6	2	141.3	1	16.3	9	1745.3	37	3064.7
780608	3	200.6	25	1065.9	1	5.5	9	557.0	0	0.0	7	724.7	45	2553.7
780613	0	0.0	11	789.3	0	0.0	4	227.2	0	0.0	5	377.3	20	1393.8
780615	0	0.0	6	296.7	3	140.9	4	287.5	0	0.0	18	1942.2	31	2667.3
780620	1	58.9	10	517.7	3	90.0	0	0.0	0	0.0	9	807.1	23	1473.7
780622	0	0.0	12	503.1	0	0.0	1	12.0	0	0.0	4	465.6	17	980.7
780627	3	1.7	4	242.6	1	0.6	0	0.0	0	0.0	7	430.1	15	675.0
780704	25	29.4	8	287.5	2	2.2	5	249.5	0	0.0	1	123.1	41	691.7
780706	11	22.2	2	155.5	0	0.0	2	148.8	0	0.0	2	191.3	17	517.8
780711	9	160.3	7	309.0	0	0.0	1	54.4	0	0.0	2	97.3	19	621.0
780713	5	7.0	5	351.8	0	0.0	2	81.4	0	0.0	1	106.8	13	547.0
780718	0	0.0	9	432.3	0	0.0	2	143.1	1	2.9	1	59.2	13	637.5
780720	0	0.0	19	154.3	0	0.0	0	0.0	0	0.0	4	223.6	23	377.9
780725	10	43.3	39	391.3	0	0.0	5	281.7	1	2.3	6	12.0	61	730.6
780801	6	46.4	11	304.8	0	0.0	1	81.5	0	0.0	0	0.0	18	432.7
780803	1	44.3	4	138.9	0	0.0	1	96.4	1	52.8	2	123.2	9	455.6
780808	1	53.5	7	538.4	0	0.0	3	263.0	1	72.7	1	109.1	13	1036.7
780810	1	60.0	7	503.3	0	0.0	1	76.5	0	0.0	1	85.2	10	725.0
780815	3	13.2	5	233.3	1	25.4	5	101.5	0	0.0	0	0.0	14	373.4
780817	2	135.7	16	222.2	0	0.0	9	15.1	0	0.0	3	456.5	30	829.5
780822	0	0.0	57	586.9	0	0.0	6	4.7	1	4.8	6	303.4	70	899.8
780823	0	0.0	6	16.6	0	0.0	1	98.0	0	0.0	0	0.0	7	114.6
780829	1	15.1	3	141.9	0	0.0	4	176.5	1	161.9	3	196.9	12	692.3
780831	1	7.8	8	521.2	0	0.0	5	297.6	0	0.0	8	763.6	22	1590.2
780905	0	0.0	9	513.0	0	0.0	5	229.1	0	0.0	6	601.6	20	1343.7
780907	0	0.0	5	103.2	0	0.0	4	168.6	0	0.0	1	103.5	10	375.3
780912	0	0.0	5	311.9	0	0.0	1	2.3	0	0.0	2	83.5	8	397.7
780914	0	0.0	8	169.5	0	0.0	10	83.8	0	0.0	6	413.7	24	667.0
780919	0	0.0	20	371.4	0	0.0	4	259.8	0	0.0	5	363.4	29	994.6
780926	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	.	0	.
780928	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	.	0	.
781004	0	0.0	55	1283.6	0	0.0	3	96.4	0	0.0	1	4.1	59	1384.1
781006	0	0.0	43	625.6	0	0.0	0	0.0	0	0.0	7	174.4	50	800.0
781010	0	0.0	28	623.5	0	0.0	1	19.4	0	0.0	0	0.0	29	642.9
781012	0	0.0	90	1595.9	0	0.0	0	0.0	1	48.0	1	4.5	92	1648.4
781017	0	0.0	48	944.1	0	0.0	5	341.5	0	0.0	0	0.0	53	1285.6

TABLE 6.1.2. THE NUMBER AND WEIGHT (GMS.) OF INDIVIDUALS FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED AT NORTH ANNA POWER STATION BY SAMPLE DATE, 1978- 1983. VALUES REPRESENT TOTALS OVER A 24-HOUR PERIOD. ABBREVIATIONS ARE: DC - DOROSOMA CEPEDIANUM, PN - POMOXIS NIGROMACULATUS, PF - PERCA FLAVESCNS, LMA -LEPOMIS MACROCHIRUS, MA - MORONE AMERICANA, OT - OTHER. THE SUFFIXES ARE T - NUMBER AND W - WEIGHT.

DATE	DCT	DCW	PNT	PNW	PFT	PFW	LMAT	LMAW	MAT	MAW	OTT	OTW	TFISH	TWT
781024	2	16.7	38	836.9	0	0.0	1	42.0	0	0.0	0	0.0	41	895.6
781026	3	69.4	34	848.6	0	0.0	1	70.5	0	0.0	0	0.0	38	988.5
781031	2	46.8	47	1011.3	0	0.0	1	35.5	0	0.0	0	0.0	50	1093.6
781102	1	78.9	49	1387.1	0	0.0	0	0.0	0	0.0	0	0.0	50	1466.0
781108	1	13.5	101	2294.4	0	0.0	0	0.0	0	0.0	1	12.0	103	2319.9
781110	3	72.3	58	1811.4	0	0.0	0	0.0	0	0.0	0	0.0	61	1883.7
781114	1	15.7	105	3550.0	0	0.0	0	0.0	0	0.0	3	14.5	109	3580.2
781120	1	10.9	75	2755.1	0	0.0	0	0.0	0	0.0	1	5.8	77	2771.8
781122	0	0.0	3	117.6	0	0.0	0	0.0	0	0.0	1	73.2	4	190.8
781128	1	66.3	126	3721.2	0	0.0	1	2.3	0	0.0	2	10.8	130	3800.6
781130	5	43.9	57	2295.1	0	0.0	0	0.0	0	0.0	5	44.0	67	2383.0
781205	6	83.4	74	3930.7	0	0.0	0	0.0	0	0.0	1	8.3	81	4022.4
781207	11	103.0	21	1181.2	0	0.0	0	0.0	0	0.0	4	22.8	36	1307.0
781212	9	91.0	26	1304.9	1	113.3	0	0.0	0	0.0	6	887.5	42	2396.7
781219	45	476.3	28	1716.1	0	0.0	0	0.0	0	0.0	2	13.0	75	2205.4
781221	41	383.5	18	1514.1	0	0.0	1	39.9	0	0.0	3	28.5	63	1966.0
781227	95	1005.8	56	4203.3	0	0.0	0	0.0	0	0.0	2	20.8	153	5229.9
781229	54	798.3	16	1225.0	0	0.0	0	0.0	0	0.0	3	313.5	73	2336.8
790103	85	934.9	49	2749.7	1	176.5	1	37.7	0	0.0	3	15.4	139	3914.2
790105	177	1718.1	16	1355.6	2	39.9	0	0.0	0	0.0	3	81.9	198	3195.5
790109	172	1888.0	17	1156.8	3	259.9	0	0.0	0	0.0	5	35.9	197	3340.6
790116	362	4019.9	18	1349.3	1	94.1	0	0.0	0	0.0	0	0.0	381	5463.3
790118	539	6637.1	52	3905.8	0	0.0	1	54.0	0	0.0	0	0.0	592	10596.9
790124	5345	4009.0	44	3757.4	4	365.0	2	66.4	0	0.0	7	42.0	5402	8239.8
790126	6315	10066.7	22	1818.0	4	201.1	2	182.5	0	0.0	3	150.2	6346	12418.5
790130	1572	7752.5	32	1931.6	2	19.4	1	0.8	0	0.0	2	94.6	1609	9798.9
790201	4028	52867.7	44	3445.0	1	77.7	2	115.9	1	12.0	5	34.0	4081	56552.3
790206	6175	73290.0	45	3463.3	1	100.6	1	105.4	0	0.0	2	84.3	6224	77043.6
790214	186	1902.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	186	1902.6
790216	418	5703.4	16	908.7	0	0.0	0	0.0	0	0.0	5	31.9	439	6644.0
790221	6369	85317.3	78	1999.7	5	47.9	1	2.7	0	0.0	3	19.1	6456	87386.7
790223	5719	77795.3	59	1489.1	5	67.3	1	2.2	3	29.5	3	39.8	5790	79423.2
790227	7400	11597.9	198	10758.3	322	11512.3	3	39.6	5	158.0	20	1202.1	7948	35268.2
790301	12384	174682.1	475	20920.0	683	23497.2	4	214.9	6	137.6	34	3403.6	13586	222855.4
790306	13516	192249.1	1366	53326.1	1904	48549.4	34	2089.2	100	4157.2	34	3758.0	16954	304129.0
790313	9287	132363.7	348	25021.7	1847	33588.3	15	623.0	6	373.3	19	1511.2	11522	193481.2
790315	10200	121253.1	1310	77367.5	2160	44061.2	10	510.4	6	244.2	23	2729.1	13709	246165.5
790320	9480	119755.6	406	26187.9	2460	40487.2	23	1009.0	2	10.6	2	117.3	12373	187567.6
790323	6490	91212.4	282	19166.0	4616	51909.6	23	1057.1	1	5.0	6	509.5	11418	163859.6
790327	2034	30645.4	443	25279.2	3900	62944.3	14	507.8	5	83.0	38	3447.8	6434	122907.5
790329	1825	20946.4	1065	45104.8	3477	43729.9	9	352.9	5	140.6	17	1214.3	6398	111488.9
790403	777	10203.7	375	10004.4	461	4394.6	7	311.9	2	28.4	18	1731.1	1640	26674.1
790410	251	2827.0	36	1431.6	6	129.3	3	148.5	2	52.0	2	16.5	300	4604.9
790412	289	3637.2	125	5470.6	20	603.9	0	0.0	0	0.0	0	0.0	434	9711.7
790417	180	2371.5	77	2552.5	15	280.9	1	62.5	2	50.1	3	108.5	278	5426.0
790419	144	1943.0	80	2335.0	17	369.3	4	103.2	1	18.0	1	121.1	247	4889.6
790424	55	735.9	59	1885.6	10	300.1	2	4.7	0	0.0	1	6.4	127	2932.7
790426	89	1076.6	64	2040.2	3	133.0	1	4.1	1	18.6	3	27.9	161	3300.4
790501	20	452.8	52	1603.9	17	351.1	10	129.6	2	92.2	6	575.9	107	3205.5
790508	4	206.6	32	1926.1	2	25.8	4	9.0	0	0.0	6	1031.9	48	3199.4

TABLE 6.1.2. THE NUMBER AND WEIGHT (GMS.) OF INDIVIDUALS FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED AT NORTH ANNA POWER STATION BY SAMPLE DATE, 1978- 1983. VALUES REPRESENT TOTALS OVER A 24-HOUR PERIOD. ABBREVIATIONS ARE: DC - DOROSOMA CEPEDIANUM, PN - POMOXIS NIGROMACULATUS, PF - PERCA FLAVESCNS, LMA -LEPOMIS MACROCHIRUS, MA - MORONE AMERICANA, OT - OTHER. THE SUFFIXES ARE T - NUMBER AND W - WEIGHT.

DATE	DCT	DCW	PNT	PNW	PFT	PFW	LMAT	LMAW	MAT	MAW	OTT	OTW	TFISH	TWT
790510	4	44.8	64	1658.8	8	170.5	9	205.5	0	0.0	3	333.5	88	2413.1
790515	6	232.4	73	3247.9	3	111.4	12	228.8	0	0.0	13	1168.0	107	4988.5
790517	3612	84740.9	69	3441.2	61	587.9	14	755.1	1	86.6	10	814.2	3767	90425.9
790522	44	977.2	28	1835.2	0	0.0	8	521.4	2	159.7	3	156.5	85	3650.0
790524	11	257.4	25	1763.3	0	0.0	9	392.5	1	70.7	2	156.8	48	2640.7
790529	9	304.6	36	2016.5	1	10.3	32	2400.3	0	0.0	4	372.1	82	5103.8
790605	17	514.9	50	2016.9	30	266.0	8	189.4	0	0.0	3	433.9	108	3421.1
790607	1	23.4	36	1510.0	2	23.6	12	273.0	0	0.0	1	125.0	52	1955.0
790612	1	20.6	46	1607.8	0	0.0	31	383.0	0	0.0	16	1997.7	94	4009.1
790614	0	0.0	12	481.0	0	0.0	19	206.3	0	0.0	6	710.4	37	1397.7
790619	0	0.0	13	745.7	0	0.0	5	94.0	0	0.0	8	1020.7	26	1860.4
790621	0	0.0	2	78.4	0	0.0	8	12.0	0	0.0	4	57.4	14	147.8
790626	1	69.9	10	595.2	0	0.0	5	9.5	0	0.0	4	273.1	20	947.7
790703	0	0.0	10	624.2	1	1.2	6	200.5	0	0.0	2	249.3	19	1075.2
790706	0	0.0	8	628.0	0	0.0	5	87.0	0	0.0	1	111.6	14	826.6
790710	0	0.0	2	174.8	0	0.0	7	502.9	1	1.0	2	220.5	12	899.2
790712	0	0.0	3	167.0	0	0.0	0	0.0	0	0.0	0	0.0	3	167.0
790717	0	0.0	6	235.7	0	0.0	6	615.6	1	164.3	2	85.1	15	1100.7
790718	2	55.0	7	441.4	1	10.7	1	2.0	0	0.0	3	319.5	14	828.6
790724	2	3.9	3	234.5	3	23.6	3	18.2	0	0.0	0	0.0	11	280.2
790731	0	0.0	6	333.2	0	0.0	5	112.3	2	4.3	1	90.4	14	540.2
790802	0	0.0	1	64.1	2	14.9	1	4.1	0	0.0	0	0.0	4	83.1
790807	0	0.0	4	261.7	0	0.0	7	156.1	4	9.8	2	186.7	17	614.3
790809	0	0.0	3	231.6	0	0.0	1	4.3	7	23.4	2	188.9	13	448.2
790814	1	51.0	5	405.6	0	0.0	2	1.7	0	0.0	2	57.0	10	515.3
790816	3	356.2	5	323.1	0	0.0	4	47.8	0	0.0	3	165.1	15	892.2
790821	1	10.1	5	296.1	0	0.0	7	208.0	0	0.0	0	0.0	13	514.2
790828	2	23.6	7	646.5	0	0.0	4	232.1	0	0.0	1	147.3	14	1049.5
790830	0	0.0	7	537.8	0	0.0	3	28.8	1	109.0	3	237.8	14	913.4
790905	0	0.0	3	275.4	0	0.0	2	2.2	2	145.1	1	95.8	8	518.5
790907	0	0.0	9	622.1	0	0.0	7	151.7	0	0.0	1	3.7	17	777.5
790911	1	62.8	8	553.0	0	0.0	4	99.0	6	548.9	0	0.0	19	1263.7
790913	0	0.0	2	173.5	1	120.0	2	6.5	5	563.2	0	0.0	10	863.2
790918	0	0.0	15	647.4	1	207.9	5	288.2	8	841.0	0	0.0	29	1984.5
790919	0	0.0	2	54.0	0	0.0	0	0.0	1	134.0	0	0.0	3	188.0
790925	1	64.5	20	1027.3	0	0.0	12	872.2	13	1062.8	1	2.8	47	3029.6
790927	2	100.0	75	2064.2	2	220.0	20	801.5	15	1511.4	2	56.3	116	4753.4
791002	1	85.4	89	1835.1	0	0.0	17	691.2	20	1747.1	4	142.4	131	4501.2
791004	1	39.9	156	4348.2	0	0.0	16	421.8	13	1001.2	7	145.9	193	5957.0
791009	0	0.0	34	1156.8	0	0.0	5	95.3	10	819.8	1	55.4	50	2127.3
791011	1	58.7	42	1610.7	0	0.0	15	387.5	9	794.3	2	53.0	69	2904.2
791016	3	58.2	109	2578.8	1	82.0	16	654.5	6	382.8	3	76.1	138	3832.4
791023	0	0.0	44	1325.4	0	0.0	2	66.3	5	370.0	3	128.3	54	1890.0
791025	0	0.0	16	397.3	0	0.0	11	204.8	5	277.7	0	0.0	32	879.8
791030	3	121.7	164	3908.5	0	0.0	12	371.1	1	140.6	0	0.0	180	4541.9
791101	4	130.5	31	907.7	0	0.0	5	127.6	3	255.7	2	116.6	45	1538.1
791106	3	87.3	57	1388.5	0	0.0	8	438.8	2	134.2	4	37.4	74	2086.2
791108	5	44.6	19	545.6	1	25.1	4	103.5	4	235.1	5	74.7	38	1028.6
791113	5	196.0	12	484.3	1	24.8	10	405.6	1	129.7	5	101.9	34	1342.3
791119	2	8.1	115	4177.1	1	224.3	3	57.4	3	285.8	8	69.3	132	4822.0

TABLE 6.1.2. THE NUMBER AND WEIGHT (GMS.) OF INDIVIDUALS FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED AT NORTH ANNA POWER STATION BY SAMPLE DATE, 1978- 1983. VALUES REPRESENT TOTALS OVER A 24-HOUR PERIOD. ABBREVIATIONS ARE: DC - DOROSOMA CEPEDIANUM, PN - POMOXIS NIGROMACULATUS, PF - PERCA FLAVESCNS, LMA -LEPOMIS MACROCHIRUS, MA - MORONE AMERICANA, OT - OTHER. THE SUFFIXES ARE T - NUMBER AND W - WEIGHT.

DATE	DCT	DCW	PNT	PNW	PFT	PFW	LMAT	LMAW	MAT	MAW	OTT	OTW	TFISH	TWT
791121	1	35.7	199	5877.7	0	0.0	13	523.7	0	0.0	14	146.4	227	6583.5
791127	2	55.1	47	2099.4	0	0.0	3	127.1	2	116.1	13	154.3	67	2552.0
791129	4	27.6	69	3120.9	0	0.0	4	138.8	3	371.7	12	131.0	92	3790.0
791204	1	45.3	106	4402.8	0	0.0	3	94.8	0	0.0	13	113.5	123	4656.4
791206	4	205.7	164	6102.4	0	0.0	4	88.4	1	77.3	13	129.1	186	6602.9
791211	6	217.6	37	2357.9	0	0.0	6	124.5	1	66.8	23	222.3	73	2989.1
791218	0	0.0	4	493.1	0	0.0	0	0.0	0	0.0	1	7.4	5	500.5
791220	8	227.8	53	3403.2	0	0.0	1	30.8	1	39.8	22	332.4	85	4034.0
791227	14	328.3	134	7812.4	0	0.0	3	28.7	0	0.0	8	79.4	159	8248.8
791229	15	405.6	84	5859.9	1	35.5	0	0.0	1	51.6	4	37.0	105	6389.6
800103	9	408.7	55	3734.5	0	0.0	2	43.1	0	0.0	5	36.7	71	4223.0
800105	5	146.5	39	2910.4	0	0.0	8	326.3	2	148.6	10	83.2	64	3615.0
800108	27	756.8	25	1577.1	0	0.0	2	67.0	0	0.0	3	407.5	57	2808.4
800115	49	1765.2	27	2059.3	0	0.0	8	373.9	0	0.0	7	70.1	91	4268.5
800117	74	1465.2	18	1256.5	0	0.0	9	351.1	0	0.0	8	674.0	109	3746.8
800122	248	3280.7	80	6927.6	0	0.0	6	265.2	0	0.0	4	28.8	338	10502.3
800124	170	2751.9	47	3305.7	1	36.6	3	9.0	1	201.7	7	112.9	229	6417.8
800129	109	2925.1	46	3325.2	2	65.7	8	231.1	0	0.0	4	29.3	169	6576.4
800131	130	3703.4	23	1670.1	0	0.0	6	129.1	1	165.3	3	1287.0	163	6954.9
800205	93	2504.0	18	1388.1	1	50.0	17	310.4	0	0.0	6	45.2	135	4297.7
800212	77	1226.8	7	430.4	3	68.0	4	122.8	0	0.0	1	11.0	92	1859.0
800214	93	1799.6	10	599.4	3	79.1	7	171.4	0	0.0	2	12.4	115	2661.9
800220	99	2192.1	11	397.1	20	709.6	5	190.6	1	129.6	3	93.9	139	3712.9
800222	79	1943.8	14	472.9	32	1061.7	9	348.9	0	0.0	4	28.5	138	3855.8
800226	260	6433.8	53	3378.5	239	6528.3	10	667.7	0	0.0	15	141.3	577	17149.6
800228	235	5299.2	65	4541.8	319	8329.5	8	377.1	0	0.0	12	88.6	639	18636.2
800305	213	6278.9	60	3399.9	670	14670.7	3	70.9	1	69.2	8	76.2	955	24565.8
800311	182	5138.5	81	4583.0	1419	34132.5	34	1319.6	2	114.5	7	57.9	1725	45346.0
800313	351	8743.0	116	4472.7	1231	26410.2	18	753.4	2	169.5	10	114.2	1728	40663.0
800318	563	11978.8	491	34305.8	1214	23223.1	7	380.9	2	106.2	10	177.3	2287	70172.1
800320	410	9872.2	297	16595.4	1667	30686.4	10	363.9	2	113.1	16	250.6	2402	57881.6
800325	388	10433.7	631	36502.3	673	10046.3	32	1181.7	1	60.0	7	196.1	1732	58420.1
800327	219	10991.3	228	10637.8	493	7084.1	9	353.0	3	223.1	8	187.7	960	29477.0
800401	369	16870.7	324	15400.1	478	5065.1	22	436.3	3	147.2	5	243.3	1201	38162.7
800408	511	15499.5	313	11958.9	41	611.3	8	348.1	0	0.0	8	168.1	881	28585.9
800410	424	16387.8	217	8241.5	21	409.8	10	196.6	0	0.0	4	193.9	676	25429.6
800415	378	15150.6	121	4971.4	4	123.5	10	141.9	0	0.0	3	14.9	516	20402.3
800417	160	6821.7	143	5518.3	14	214.2	19	284.6	0	0.0	1	9.3	337	12848.1
800422	84	3468.7	53	2118.9	8	134.8	21	255.4	0	0.0	2	165.1	168	6142.9
800424	54	2277.0	62	2242.2	2	32.7	31	246.2	1	13.2	2	170.7	152	4982.0
800429	2	91.0	33	1313.3	2	284.0	33	303.6	2	103.2	0	0.0	72	2095.1
800506	4	293.4	69	4412.9	1	27.2	9	130.1	0	0.0	3	106.2	86	4969.8
800508	3	135.2	128	7377.5	0	0.0	37	542.4	1	9.9	2	200.5	171	8265.5
800513	3	146.1	178	12169.5	2	71.9	23	316.6	5	249.9	1	31.9	212	12985.9
800515	2	108.7	200	14483.7	1	21.0	47	596.4	4	278.4	5	490.1	259	15978.3
800520	4	81.4	155	10232.1	0	0.0	32	1350.7	2	102.7	4	229.3	197	11996.2
800522	3	138.1	127	8143.9	1	22.0	54	2010.8	6	349.2	5	592.4	196	11256.4
800527	1	24.2	73	4323.0	0	0.0	36	1030.9	1	53.9	1	10.9	112	5442.9
800603	1	85.1	7	382.1	1	27.5	30	441.4	1	62.2	2	3143.4	42	4141.7
800606	0	0.0	25	1277.9	0	0.0	63	650.0	5	227.6	3	161.7	96	2317.2

TABLE 6.1.2. THE NUMBER AND WEIGHT (GMS.) OF INDIVIDUALS FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED AT NORTH ANNA POWER STATION BY SAMPLE DATE, 1978- 1983. VALUES REPRESENT TOTALS OVER A 24-HOUR PERIOD. ABBREVIATIONS ARE: DC - DOROSOMA CEPEDIANUM, PN - POMOXIS NIGROMACULATUS, PF - PERCA FLAVESCNS, LMA -LEPOMIS MACROCHIRUS, MA - MORONE AMERICANA, OT - OTHER. THE SUFFIXES ARE T - NUMBER AND W - WEIGHT.

DATE	DCT	DCW	PNT	PNW	PFT	PFW	LMAT	LMAW	MAT	MAW	OTT	OTW	TFISH	TWT
800610	1	143.8	19	1187.2	0	0.0	69	877.7	2	108.4	2	120.5	93	2437.6
800612	0	0.0	17	1203.7	0	0.0	27	159.3	2	183.0	4	351.0	50	1897.0
800617	2	155.6	10	851.6	0	0.0	21	394.7	1	33.0	3	291.7	37	1726.6
800619	1	78.9	11	818.7	1	121.2	12	320.0	2	62.7	1	11.0	28	1412.5
800624	0	0.0	10	723.9	0	0.0	14	276.1	0	0.0	6	5.2	30	1005.2
800701	0	0.0	8	583.4	1	1.3	11	240.7	0	0.0	2	59.2	22	884.6
800703	2	126.8	4	349.7	0	0.0	4	102.9	0	0.0	1	125.0	11	704.4
800708	3	168.8	12	868.3	0	0.0	16	216.3	3	70.2	3	196.9	37	1520.5
800710	2	38.6	21	1884.3	0	0.0	28	333.2	0	0.0	6	17.2	57	2273.3
800715	4	8.2	8	713.8	0	0.0	22	337.5	5	131.6	3	19.9	42	1211.0
800717	5	79.1	7	488.8	0	0.0	18	145.1	2	6.0	1	1871.8	33	2590.8
800722	5	19.4	13	522.9	1	2.0	48	282.5	22	57.7	3	41.0	92	925.5
800729	0	0.0	16	1114.0	0	0.0	12	202.3	0	0.0	1	170.4	29	1486.7
800731	1	49.9	12	887.8	0	0.0	23	454.6	0	0.0	1	4.5	37	1396.8
800805	1	91.1	5	233.2	0	0.0	16	48.1	0	0.0	1	4.9	23	377.3
800807	2	132.6	8	700.0	0	0.0	11	125.6	1	3.1	0	0.0	22	961.3
800812	1	83.8	4	333.7	0	0.0	96	331.7	3	28.7	2	7.4	106	785.3
800814	1	5.0	7	403.5	2	6.2	54	60.3	6	72.7	1	5.6	71	553.3
800819	1	49.5	54	3821.7	0	0.0	30	68.0	1	2.9	1	152.3	87	4094.4
800820	0	0.0	14	868.4	0	0.0	16	20.3	1	5.2	0	0.0	31	893.9
800826	0	0.0	28	1634.8	1	3.2	26	58.7	9	29.7	0	0.0	64	1726.4
800828	2	59.1	23	1290.8	0	0.0	33	540.9	0	0.0	0	0.0	58	1890.8
800903	1	9.0	38	1969.7	0	0.0	37	387.4	3	63.4	4	1327.5	83	3757.0
800905	1	77.0	35	1782.1	0	0.0	27	101.5	4	183.4	3	118.9	70	2262.9
800909	2	72.8	25	1513.1	0	0.0	27	102.4	0	0.0	2	6.1	56	1694.4
800911	5	172.3	45	2804.9	0	0.0	22	244.7	1	30.4	1	340.5	74	3592.8
800916	2	141.2	24	1224.3	0	0.0	16	207.3	1	3.4	3	73.1	46	1649.3
800923	0	0.0	32	971.6	0	0.0	13	80.6	0	0.0	2	11.2	47	1063.4
800925	1	22.6	34	1755.7	0	0.0	13	85.8	1	125.7	0	0.0	49	1989.8
800930	4	266.0	111	3776.5	1	35.2	60	638.3	0	0.0	2	8.0	178	4724.0
801002	7	309.7	181	4641.8	1	39.7	35	434.9	2	69.2	2	96.9	228	5592.2
801007	3	147.1	166	5403.4	0	0.0	23	298.1	0	0.0	5	22.4	197	5871.0
801014	3	140.3	157	6120.2	0	0.0	24	412.6	5	301.6	3	8.2	192	6982.9
801016	3	157.0	216	8253.1	0	0.0	21	151.2	3	90.6	4	17.5	247	8669.4
801021	4	190.5	109	4148.1	0	0.0	29	129.0	5	310.4	2	19.0	149	4797.0
801023	2	54.6	96	2671.2	0	0.0	71	789.6	1	49.5	2	4.5	172	3569.4
801028	4	145.2	634	27918.8	0	0.0	24	280.0	6	188.6	2	120.2	670	28652.8
801030	9	474.0	566	23846.8	0	0.0	28	432.8	3	59.5	4	36.1	610	24849.2
801104	9	501.6	610	24196.0	0	0.0	37	622.7	3	119.8	5	21.1	664	25461.2
801112	8	389.8	91	3740.7	0	0.0	124	670.5	3	194.3	12	822.7	238	5818.0
801114	11	567.2	93	3952.2	0	0.0	70	327.9	1	8.0	16	105.2	191	4960.5
801118	20	801.5	170	8435.8	0	0.0	198	913.8	1	119.4	30	172.3	419	10442.8
801120	14	549.7	224	10142.9	0	0.0	85	650.2	4	182.7	22	267.2	349	11792.7
801124	13	578.0	78	4007.0	0	0.0	20	257.0	1	39.8	19	158.7	131	5040.5
801126	16	767.9	93	5026.5	0	0.0	28	153.1	2	22.4	32	265.1	171	6235.0
801202	27	1409.4	104	6102.0	0	0.0	18	81.9	1	123.1	77	758.4	227	8474.8
801209	38	1969.8	66	4102.6	0	0.0	20	376.7	1	58.3	63	586.5	188	7093.9
801211	38	1765.7	54	3206.1	0	0.0	12	164.6	2	82.5	30	282.8	136	5501.7
801216	73	3304.4	155	12329.6	0	0.0	8	135.9	1	61.8	86	849.2	323	16680.9
801218	55	2816.9	91	7412.4	1	15.8	16	290.3	1	9.4	101	968.4	265	11513.2

TABLE 6.1.2. THE NUMBER AND WEIGHT (GMS.) OF INDIVIDUALS FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED AT NORTH ANNA POWER STATION BY SAMPLE DATE, 1978- 1983. VALUES REPRESENT TOTALS OVER A 24-HOUR PERIOD. ABBREVIATIONS ARE: DC - DOROSOMA CEPEDIANUM, PN - POMOXIS NIGROMACULATUS, PF - PERCA FLAVESCNS, LMA -LEPOMIS MACROCHIRUS, MA - MORONE AMERICANA, OT - OTHER. THE SUFFIXES ARE T - NUMBER AND W - WEIGHT.

DATE	DCT	DCW	PNT	PNW	PFT	PFW	LMAT	LMAW	MAT	MAW	OTT	OTW	TFISH	TWT
801223	77	3506.7	39	2233.0	0	0.0	12	233.9	2	62.7	39	421.6	169	6457.9
801227	166	6284.5	37	2358.3	1	29.9	17	315.5	1	95.6	51	512.8	273	9596.6
801230	72	4010.3	6	414.4	0	0.0	8	195.8	6	169.4	34	365.5	126	5155.4
810106	96	5683.8	13	814.1	0	0.0	6	150.5	0	0.0	16	195.3	131	6843.7
810108	713	43263.1	12	796.7	0	0.0	6	285.9	1	9.0	24	1876.9	756	46231.6
810114	1358	80696.2	25	1463.6	0	0.0	3	158.8	1	6.6	12	150.8	1399	82476.0
810116	92	6067.9	4	202.5	0	0.0	2	52.1	0	0.0	4	37.1	102	6359.6
810120	55	3247.8	8	427.2	2	203.1	4	70.5	0	0.0	4	57.1	73	4005.7
810122	119	8370.2	11	656.2	0	0.0	6	160.4	0	0.0	8	376.3	144	9563.1
810127	140	9251.2	61	3807.1	0	0.0	8	183.9	0	0.0	38	323.6	247	13565.8
810203	199	13519.6	28	1581.4	2	65.0	6	134.5	0	0.0	37	383.2	272	15683.7
810205	460	30813.0	30	1681.3	3	201.3	5	52.7	0	0.0	19	183.2	517	32931.5
810210	515	32495.4	65	3501.7	0	0.0	4	47.6	1	32.0	15	176.4	600	36253.1
810212	541	35253.9	36	2282.8	0	0.0	12	240.5	1	39.2	33	401.0	623	38217.4
810218	456	29231.6	88	4558.3	36	1041.1	19	385.1	0	0.0	16	147.2	615	35363.3
810220	124	7920.2	209	12226.0	150	4702.2	11	269.9	0	0.0	44	490.2	538	25608.5
810224	76	5492.6	234	13341.9	448	11839.0	35	868.2	3	256.1	40	479.5	836	32277.3
810303	119	7560.9	348	19302.4	242	5678.2	17	367.6	0	0.0	36	385.2	762	33294.3
810305	122	7515.7	143	8025.0	271	5842.4	14	259.0	1	6.0	37	350.0	588	21998.1
810310	173	11635.5	128	6908.0	96	2266.8	10	198.1	0	0.0	13	143.9	420	21152.3
810312	483	29976.6	164	8664.2	144	3185.6	8	190.4	0	0.0	15	165.7	814	42182.5
810317	586	39204.9	513	27665.2	62	1514.0	20	358.1	0	0.0	19	248.4	1200	68990.6
810319	1662	105209.5	359	19054.0	24	553.8	2	70.4	2	127.5	24	341.6	2073	125356.8
810324	693	45320.2	161	7628.6	40	992.7	10	208.6	1	47.7	21	240.3	926	54438.1
810331	500	28999.2	425	23766.2	82	1348.3	6	149.0	1	6.2	34	339.0	1048	54607.9
810402	623	33953.2	338	17893.1	89	1198.0	15	213.0	1	11.7	27	576.1	1093	53845.1
810407	1642	85724.4	232	8760.8	49	557.6	23	151.8	7	170.1	14	394.0	1967	95758.7
810409	1198	56745.4	103	4452.9	21	148.9	8	54.4	14	223.6	7	85.5	1351	61710.7
810414	1493	70105.4	69	2733.8	11	103.7	73	309.7	32	838.2	10	149.3	1688	74240.1
810416	496	26592.7	59	2141.1	5	55.2	77	300.7	17	304.2	5	402.0	659	29795.9
810421	128	6527.1	27	635.1	8	109.4	103	430.9	18	408.2	2	1026.6	286	9137.3
810428	54	2641.1	41	1794.1	3	55.8	45	160.7	16	425.9	4	3957.9	163	9035.5
810430	27	1532.8	32	1717.4	0	0.0	84	353.5	6	189.1	6	279.4	155	4072.2
810505	14	696.9	20	674.7	0	0.0	21	78.8	3	128.0	8	843.2	66	2421.6
810507	11	468.0	21	1148.1	1	69.5	42	256.4	6	207.1	10	586.3	91	2735.4
810512	2	158.0	24	1797.4	0	0.0	46	309.4	4	93.4	4	2024.9	80	4383.1
810514	0	0.0	22	1511.4	0	0.0	38	212.5	1	62.0	3	175.5	64	1961.4
810519	5	338.9	49	2953.2	1	41.9	74	554.5	5	234.4	4	344.7	138	4467.6
810526	2	93.0	54	3585.2	1	23.6	40	885.1	3	107.7	2	119.8	102	4814.4
810529	2	75.6	70	4816.3	1	10.4	25	446.5	0	0.0	6	504.5	104	5853.3
810602	3	103.2	25	1659.3	0	0.0	51	1130.7	2	90.1	3	298.1	84	3281.4
810604	2	114.7	14	1046.5	0	0.0	58	584.7	1	10.0	4	189.5	79	1945.4
810609	0	0.0	7	537.7	0	0.0	156	1122.9	2	141.7	0	0.0	165	1802.3
810611	1	29.4	13	1087.5	0	0.0	160	991.4	1	36.6	2	129.3	177	2274.2
810616	1	43.3	41	3746.0	0	0.0	80	1090.2	7	333.9	3	2171.4	132	7384.8
810623	3	156.2	6	540.0	0	0.0	16	423.7	8	425.5	0	0.0	33	1545.4
810625	1	50.4	10	720.7	0	0.0	10	215.0	5	312.3	2	2.1	28	1300.5
810630	1	59.4	12	943.1	0	0.0	7	253.2	7	447.3	1	74.3	28	1777.3
810702	1	37.1	20	1440.4	0	0.0	13	316.6	10	567.5	6	518.9	50	2880.5
810707	4	39.9	37	2677.0	0	0.0	25	371.8	16	923.0	3	161.8	85	4173.5

TABLE 6.1.2. THE NUMBER AND WEIGHT (GMS.) OF INDIVIDUALS FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED AT NORTH ANNA POWER STATION BY SAMPLE DATE, 1978- 1983. VALUES REPRESENT TOTALS OVER A 24-HOUR PERIOD. ABBREVIATIONS ARE: DC - DOROSOMA CEPEDIANUM, PN - POMOXIS NIGROMACULATUS, PF - PERCA FLAVESCNS, LMA -LEPOMIS MACROCHIRUS, MA - MORONE AMERICANA, OT - OTHER. THE SUFFIXES ARE T - NUMBER AND W - WEIGHT.

DATE	DCT	DCW	PNT	PNW	PFT	PFW	LMAT	LMAW	MAT	MAW	OTT	OTW	TFISH	TWT
810709	3	39.3	33	2085.1	0	0.0	10	163.7	6	406.1	1	125.6	53	2819.8
810714	2	171.5	59	3648.9	0	0.0	30	244.4	7	371.4	4	340.2	102	4776.4
810721	1	61.7	27	1673.7	0	0.0	10	58.3	5	249.9	4	125.9	47	2169.5
810723	0	0.0	19	1130.9	0	0.0	7	100.9	5	386.8	2	137.8	33	1756.4
810728	1	56.8	31	2022.0	0	0.0	19	109.4	6	336.4	3	233.0	60	2757.6
810730	3	137.0	28	1865.7	1	0.9	20	199.6	9	414.6	1	96.9	62	2714.7
810804	5	156.1	32	1905.1	0	0.0	7	117.3	4	109.8	2	111.3	50	2399.6
810806	5	267.6	23	1443.4	0	0.0	21	130.1	10	458.3	5	453.0	64	2752.4
810811	8	440.7	15	1048.3	0	0.0	194	331.1	6	329.8	4	231.2	227	2381.1
810818	7	284.2	27	1800.2	0	0.0	85	161.6	8	291.1	2	223.0	129	2760.1
810820	20	702.2	58	3623.3	0	0.0	94	399.5	11	477.9	6	261.5	189	5464.4
810825	7	174.1	70	3779.7	1	26.5	20	90.8	5	244.0	3	203.9	106	4519.0
810827	4	159.5	45	2534.2	0	0.0	3	4.7	7	328.2	1	119.1	60	3145.7
810901	7	416.4	49	2783.2	0	0.0	1	17.8	4	175.1	2	137.3	63	3529.8
810903	4	142.3	43	2335.8	0	0.0	5	24.3	5	240.1	2	64.9	59	2807.4
810910	9	413.6	63	3151.5	0	0.0	16	264.7	6	343.3	2	96.6	96	4269.7
810916	12	504.1	19	1228.7	0	0.0	15	82.9	3	153.4	1	74.2	50	2043.3
810918	9	386.2	11	516.1	0	0.0	28	195.3	2	194.7	2	82.2	52	1374.5
810922	14	530.5	132	6449.4	0	0.0	14	43.7	6	186.6	3	25.4	169	7235.6
810924	16	623.7	44	2171.0	0	0.0	6	109.4	8	353.4	1	71.9	75	3329.4
810929	14	519.5	65	3154.8	1	11.3	9	22.7	3	141.2	0	0.0	92	3849.5
811001	9	334.5	96	4448.6	0	0.0	5	16.3	4	180.8	5	94.1	119	5074.3
811006	13	585.4	127	5577.6	0	0.0	13	105.0	3	158.2	6	328.5	162	6754.7
811014	8	279.7	137	5896.8	0	0.0	5	24.6	4	261.6	0	0.0	154	6462.7
811016	14	738.7	178	7002.4	0	0.0	12	82.2	2	78.6	1	5.4	207	7907.3
811020	22	890.3	339	16950.4	0	0.0	13	51.0	0	0.0	3	10.8	377	17902.5
811022	11	445.9	113	7692.5	0	0.0	16	88.3	7	335.3	1	87.3	148	8649.3
811027	22	843.4	367	17472.9	0	0.0	59	171.4	7	373.8	4	55.8	459	18917.3
811029	26	843.3	288	15540.7	0	0.0	77	301.5	9	440.2	7	291.8	407	17417.5
811103	34	1360.9	79	3600.2	0	0.0	180	535.8	10	403.7	12	241.9	315	6142.5
811109	31	1102.6	205	9395.9	1	22.5	518	1508.8	8	427.7	31	232.0	794	12689.5
811113	59	2361.8	40	1588.6	0	0.0	339	1573.0	17	816.4	49	531.3	504	6871.1
811117	54	2333.3	49	2224.5	2	48.5	106	391.7	18	906.7	60	577.4	289	6482.1
811119	39	1510.2	74	3445.6	3	64.6	80	276.1	7	301.7	46	575.8	249	6174.0
811123	48	1945.8	59	2386.5	3	75.2	65	212.3	16	740.6	72	810.4	263	6170.8
811125	59	2427.8	51	2120.8	1	17.0	88	246.5	23	1117.4	61	634.9	283	6564.4
811201	70	2701.4	13	666.4	0	0.0	23	68.3	12	553.3	40	343.7	158	4333.1
811208	113	4463.7	13	547.5	0	0.0	10	62.8	11	541.4	30	321.0	177	5936.4
811210	95	3309.1	30	1322.5	0	0.0	50	281.3	20	984.4	37	397.7	232	6295.0
811216	103	4398.9	32	1433.1	4	67.7	29	164.7	28	1466.1	45	425.8	241	7956.3
811218	158	5767.4	43	1967.8	1	14.8	13	99.1	18	900.5	38	419.4	271	9169.0
811221	78	2963.2	22	1014.0	0	0.0	6	50.5	12	653.9	13	115.5	131	4797.1
811223	146	6661.7	28	1303.9	1	16.5	3	40.3	28	1385.9	19	222.3	225	9630.6
811229	115	5094.8	46	2214.7	1	94.4	11	211.2	19	925.3	21	309.2	213	8849.6
820105	136	5797.7	31	1346.2	0	0.0	11	194.3	6	285.4	21	205.7	205	7829.3
820107	103	4253.7	33	1383.4	0	0.0	7	182.6	10	549.0	6	70.3	159	6439.0
820112	75	3605.3	23	996.9	0	0.0	2	78.0	11	701.7	7	95.8	118	5477.7
820114	230	10933.8	34	1486.9	2	59.7	5	225.1	20	1152.1	10	534.9	301	14392.5
820119	113	6616.5	69	3086.2	0	0.0	5	168.4	18	989.5	4	54.4	209	10915.0
820121	261	13748.7	160	7060.0	2	36.7	8	236.5	19	1045.7	9	177.9	459	22305.5

TABLE 6.1.2. THE NUMBER AND WEIGHT (GMS.) OF INDIVIDUALS FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED AT NORTH ANNA POWER STATION BY SAMPLE DATE, 1978- 1983. VALUES REPRESENT TOTALS OVER A 24-HOUR PERIOD. ABBREVIATIONS ARE: DC - DOROSOMA CEPEDIANUM, PN - POMOXIS NIGROMACULATUS, PF - PERCA FLAVESCNS, LMA -LEPOMIS MACROCHIRUS, MA - MORONE AMERICANA, OT - OTHER. THE SUFFIXES ARE T - NUMBER AND W - WEIGHT.

DATE	DCT	DCW	PNT	PNW	PFT	PFW	LMAT	LMAW	MAT	MAW	OTT	OTW	TFISH	TWT
820126	151	11119.3	94	5047.5	3	86.4	14	181.6	12	466.6	2	26.4	276	16927.8
820127	19	1386.4	11	476.2	0	0.0	1	3.5	1	72.1	0	0.0	32	1938.2
820202	242	14338.7	210	8489.0	0	0.0	12	290.3	20	988.6	13	362.3	497	24468.9
820204	261	14599.3	883	35694.7	0	0.0	15	442.9	23	1111.0	13	244.2	1195	52092.1
820209	196	11054.0	110	3597.8	11	310.9	13	236.9	12	652.4	5	197.1	347	16049.1
820211	215	17591.2	158	6918.1	10	294.5	14	303.4	20	1104.1	10	124.5	427	26335.8
820217	76	3923.8	147	6321.1	32	803.0	5	80.1	9	368.2	3	52.4	272	11548.6
820219	251	15372.9	222	11137.1	63	1549.2	22	571.7	25	1254.2	6	124.5	589	30009.6
820223	200	9056.5	351	15427.3	186	4551.9	26	708.6	49	1837.8	16	245.6	828	31827.7
820302	330	11001.5	237	10784.5	527	11095.2	15	299.3	62	3073.9	16	324.5	1187	36578.9
820304	333	19073.8	386	16944.6	294	5912.5	12	196.2	38	1818.1	9	208.8	1072	44154.0
820309	399	15884.1	213	9507.8	360	6607.0	14	281.9	42	2107.8	7	291.7	1035	34680.3
820311	86	3560.5	169	7744.4	375	8281.3	12	177.7	27	880.9	9	171.2	678	20816.0
820316	131	5501.9	189	9296.5	374	7102.0	12	193.6	34	1686.9	13	262.3	753	24043.2
820318	155	5265.6	183	8497.0	274	5223.7	12	196.0	35	1684.0	8	326.1	667	21192.4
820323	348	9279.5	311	14435.7	243	3865.6	54	314.4	80	3934.1	18	1919.4	1054	33748.7
820330	169	6047.0	287	12843.2	58	1171.5	17	151.5	76	3383.7	8	170.8	615	23767.7
820401	135	4090.3	301	12585.8	39	566.1	11	81.4	67	2780.4	8	80.3	561	20184.3
820406	65	1905.7	320	14561.8	26	458.2	26	72.9	74	3125.4	3	28.6	514	20152.6
820408	89	3033.5	206	9031.3	23	480.1	45	122.4	59	2941.1	3	133.7	425	15742.1
820414	71	2027.0	186	8198.7	22	333.6	32	196.2	23	1079.0	5	253.3	339	12087.8
820416	57	1389.0	134	5794.9	48	757.2	27	127.3	24	945.3	2	6.9	292	9020.6
820420	28	668.5	67	2689.5	5	102.2	17	70.9	22	785.7	17	647.4	156	4964.2
820427	4	146.5	27	994.0	3	41.4	7	23.2	22	831.0	8	136.2	71	2172.3
820429	4	142.1	47	1890.4	11	145.7	23	74.9	16	877.6	5	139.8	106	3270.5
820504	0	0.0	41	1557.9	3	59.1	15	50.4	32	1391.6	0	0.0	91	3059.0
820506	0	0.0	28	1038.5	1	26.2	18	58.5	24	1193.9	2	81.7	73	2398.8
820511	0	0.0	21	858.5	2	80.3	15	41.8	30	1504.7	1	101.7	69	2587.0
820513	0	0.0	17	816.4	1	25.0	4	14.7	45	2349.8	1	7.6	68	3213.5
820518	0	0.0	42	2256.4	1	26.0	32	197.8	23	1224.7	2	235.7	100	3940.6
820525	2	111.8	12	734.1	0	0.0	16	218.7	44	2174.1	2	192.0	76	3430.7
820527	2	56.7	10	652.9	0	0.0	3	32.5	23	1117.2	0	0.0	38	1859.3
820602	2	106.6	15	772.7	0	0.0	46	369.6	19	819.1	2	97.8	84	2165.8
820604	1	26.1	6	485.0	0	0.0	43	316.8	16	827.8	4	429.0	70	2084.7
820608	1	73.8	12	853.4	0	0.0	55	343.3	12	509.9	4	274.8	84	2055.2
820610	0	0.0	4	236.9	0	0.0	11	54.1	4	182.6	2	157.6	21	631.2
820615	0	0.0	9	639.6	0	0.0	5	22.5	5	273.8	1	61.9	20	997.8
820622	0	0.0	10	623.4	0	0.0	3	92.6	1	10.1	2	8.9	16	735.0
820624	0	0.0	10	799.9	0	0.0	1	2.3	5	200.2	1	7.5	17	1009.9
820629	0	0.0	8	517.5	0	0.0	4	98.5	2	21.9	0	0.0	14	637.9
820701	0	0.0	29	1654.9	0	0.0	2	30.6	1	97.0	2	165.4	34	1947.9
820707	0	0.0	4	351.7	1	19.2	2	13.6	4	208.6	0	0.0	11	593.1
820709	0	0.0	2	261.6	1	.	3	13.5	1	13.4	0	0.0	7	288.5
820713	2	68.9	1	73.8	1	1.2	2	1.2	8	63.4	1	1.2	15	209.7
820720	1	69.8	6	443.8	2	45.8	10	37.6	5	105.5	0	0.0	24	702.5
820722	0	0.0	3	280.7	0	0.0	10	35.3	2	30.9	0	0.0	15	346.9
820727	0	0.0	2	187.8	0	0.0	6	35.2	4	45.2	3	1652.6	15	1920.8
820729	0	0.0	1	94.3	0	0.0	5	21.0	2	5.0	2	173.3	10	293.6
820803	0	0.0	2	141.7	0	0.0	4	18.5	2	52.7	2	223.7	10	436.6
820805	0	0.0	0	0.0	0	0.0	4	4.9	2	5.4	2	167.0	8	177.3

TABLE 6.1.2. THE NUMBER AND WEIGHT (GMS.) OF INDIVIDUALS FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED AT NORTH ANNA POWER STATION BY SAMPLE DATE, 1978- 1983. VALUES REPRESENT TOTALS OVER A 24-HOUR PERIOD. ABBREVIATIONS ARE: DC - DOROSOMA CEPEDIANUM, PN - POMOXIS NIGROMACULATUS, PF - PERCA FLAVESCNS, LMA -LEPOMIS MACROCHIRUS, MA - MORONE AMERICANA, OT - OTHER. THE SUFFIXES ARE T - NUMBER AND W - WEIGHT.

DATE	DCT	DCW	PNT	PNW	PFT	PFW	LMAT	LMAW	MAT	MAW	OTT	OTW	TFISH	TWT
820812	0	0.0	2	104.7	0	0.0	43	55.3	2	30.8	1	31.9	48	222.7
820817	0	0.0	1	95.4	0	0.0	8	68.3	2	81.6	0	0.0	11	245.3
820819	0	0.0	2	97.3	0	0.0	9	26.9	0	0.0	0	0.0	11	124.2
820824	0	0.0	1	129.9	0	0.0	6	4.9	1	3.4	0	0.0	8	138.2
820826	0	0.0	0	0.0	1	22.7	4	20.6	0	0.0	1	163.8	6	207.1
820831	0	0.0	0	0.0	0	0.0	6	8.4	1	47.2	0	0.0	7	55.6
820902	0	0.0	2	178.9	0	0.0	3	12.2	1	24.6	0	0.0	6	215.7
820909	0	0.0	2	40.8	0	0.0	3	1.4	0	0.0	1	88.8	6	131.0
820914	0	0.0	0	0.0	0	0.0	8	24.7	0	0.0	0	0.0	8	24.7
820916	0	0.0	0	0.0	0	0.0	11	38.4	0	0.0	1	101.5	12	139.9
820921	0	0.0	0	0.0	0	0.0	9	51.2	0	0.0	0	0.0	9	51.2
820923	0	0.0	0	0.0	0	0.0	20	36.2	3	50.5	0	0.0	23	86.7
820928	0	0.0	7	350.9	0	0.0	6	75.5	0	0.0	0	0.0	13	426.4
820930	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	.	0	.
821007	1	24.3	1	12.8	0	0.0	0	0.0	0	0.0	1	127.7	3	164.8
821012	0	0.0	1	49.3	0	0.0	0	0.0	0	0.0	0	0.0	1	49.3
821014	0	0.0	6	277.3	0	0.0	6	53.9	0	0.0	0	0.0	12	331.2
821019	0	0.0	4	156.2	0	0.0	0	0.0	0	0.0	0	0.0	4	156.2
821021	0	0.0	6	294.1	0	0.0	0	0.0	0	0.0	0	0.0	6	294.1
821026	1	20.0	14	582.0	0	0.0	12	66.4	1	75.1	0	0.0	28	743.5
821028	0	0.0	16	696.3	0	0.0	5	108.5	0	0.0	1	3.7	22	808.5
821104	1	3.2	11	442.7	1	20.0	3	53.4	1	31.3	0	0.0	17	550.6
821109	1	30.7	5	234.2	0	0.0	3	34.7	1	139.8	1	9.7	11	449.1
821113	3	30.0	22	1243.0	1	6.0	6	66.0	2	57.0	3	852.0	37	2254.0
821116	1	45.5	5	254.5	0	0.0	5	18.1	2	85.8	7	56.4	20	460.3
821118	0	0.0	8	316.8	1	21.6	2	17.8	2	32.2	12	252.5	25	640.9
821122	0	0.0	14	721.2	0	0.0	3	50.2	0	0.0	2	16.6	19	788.0
821124	1	3.7	11	469.5	0	0.0	4	59.6	1	31.5	2	16.5	19	580.8
821202	1	4.2	6	427.7	0	0.0	7	173.4	2	94.2	1	3.3	17	702.8
821207	6	197.8	6	504.4	0	0.0	1	11.9	0	0.0	3	2810.2	16	3524.3
821209	3	13.5	0	0.0	0	0.0	0	0.0	4	145.9	0	0.0	7	159.4
821214	11	85.3	5	252.9	0	0.0	3	25.8	3	238.9	3	30.2	25	633.1
821216	8	68.4	2	108.1	0	0.0	1	2.6	6	281.2	3	24.1	20	484.4
821221	14	101.1	3	219.5	0	0.0	0	0.0	3	90.7	4	48.6	24	459.9
821223	3	23.0	1	131.6	0	0.0	0	0.0	0	0.0	2	17.9	6	172.5
821228	1	4.9	2	152.2	0	0.0	0	0.0	2	53.2	5	38.1	10	248.4
830104	0	0.0	1	71.0	0	0.0	3	37.9	1	73.0	6	53.9	11	235.8
830106	3	24.9	3	144.9	0	0.0	0	0.0	1	51.5	2	14.1	9	235.4
830111	1	7.9	0	0.0	0	0.0	0	0.0	2	45.3	1	13.1	4	66.3
830113	0	0.0	2	82.3	0	0.0	0	0.0	5	197.8	0	0.0	7	280.1
830118	7	77.9	4	184.1	0	0.0	1	8.7	3	68.4	6	85.5	21	424.6
830120	0	0.0	0	0.0	0	0.0	0	0.0	1	1.2	5	55.9	6	57.1
830125	3	20.5	0	0.0	0	0.0	1	11.2	2	141.7	4	41.7	10	215.1
830201	0	0.0	4	160.1	0	0.0	6	160.9	0	0.0	2	17.8	12	338.8
830203	0	0.0	2	82.4	1	35.9	0	0.0	0	0.0	2	23.9	5	142.2
830208	1	20.7	1	75.0	0	0.0	3	28.4	0	0.0	3	58.9	8	183.0
830210	12	219.6	13	718.8	0	0.0	1	69.4	1	39.9	2	31.8	29	1079.5
830215	1	4.3	2	108.3	1	18.7	1	29.1	0	0.0	6	95.4	11	255.8
830217	5	255.3	4	198.9	3	109.3	0	0.0	2	16.2	7	228.0	21	807.7
830223	2	14.8	10	434.5	23	1107.5	12	310.7	2	115.6	6	67.4	55	2050.5

TABLE 6.1.2. THE NUMBER AND WEIGHT (GMS.) OF INDIVIDUALS FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED AT NORTH ANNA POWER STATION BY SAMPLE DATE, 1978- 1983. VALUES REPRESENT TOTALS OVER A 24-HOUR PERIOD. ABBREVIATIONS ARE: DC - DOROSOMA CEPEDIANUM, PN - POMOXIS NIGROMACULATUS, PF - PERCA FLAVESCNS, LMA -LEPOMIS MACROCHIRUS, MA - MORONE AMERICANA, OT - OTHER. THE SUFFIXES ARE T - NUMBER AND W - WEIGHT.

DATE	DCT	DCW	PNT	PNW	PFT	PFW	LMAT	LMAW	MAT	MAW	OTT	OTW	TFISH	TWT
830301	2	71.0	14	573.8	31	832.0	3	120.3	7	378.6	6	53.8	63	2029.5
830303	6	263.4	12	519.9	70	1893.2	1	10.3	9	401.3	7	60.4	105	3148.5
830308	3	88.9	39	1863.2	76	1416.3	13	208.6	3	116.9	11	101.6	145	3795.5
830310	3	44.4	23	1272.9	58	1312.6	2	26.0	3	157.6	7	126.2	96	2939.7
830315	4	103.0	42	2112.2	40	797.0	4	53.4	7	256.5	14	357.7	111	3679.8
830317	2	33.0	33	1667.6	26	575.3	2	18.7	6	331.9	9	67.7	78	2694.2
830321	18	403.8	69	3407.9	102	1373.6	8	212.8	13	437.5	16	362.3	226	6197.9
830329	103	1405.6	108	5500.5	10	202.4	4	106.9	17	673.2	7	53.8	249	7942.4
830331	82	1642.1	106	4756.5	15	254.1	0	0.0	16	666.6	8	294.0	227	7613.3
830405	35	539.1	42	1854.1	8	180.3	2	17.3	5	171.7	11	198.0	103	2960.5
830407	33	555.1	29	1335.6	7	116.2	6	85.5	9	273.5	4	228.1	88	2594.0
830412	46	1099.0	43	2083.3	4	128.9	2	56.2	11	504.9	2	20.2	108	3892.5
830414	31	709.5	46	1898.5	4	83.4	4	40.4	11	456.4	3	141.0	99	3329.2
830419	50	1044.2	143	6998.2	34	707.5	8	25.4	21	829.7	10	252.7	266	9857.7
830426	72	1399.5	556	26666.4	161	2265.1	7	27.0	55	2306.6	6	45.8	857	32710.4
830428	125	2168.5	448	21079.6	215	2422.5	10	129.7	69	2315.4	14	120.4	881	28236.1
830503	1	4.3	111	4056.0	5	82.1	13	142.6	64	1714.5	16	241.2	210	6240.7
830505	10	299.5	89	3391.3	7	168.9	8	67.6	46	1326.9	5	71.8	165	5326.0
830510	4	131.5	20	747.5	0	0.0	9	34.5	30	1226.1	0	0.0	63	2139.6
830512	1	81.7	9	397.9	1	14.1	2	4.0	7	374.6	3	161.2	23	1033.5
830517	1	18.9	28	1418.8	0	0.0	15	70.6	10	437.0	2	10.7	56	1956.0
830524	0	0.0	55	3364.1	0	0.0	7	151.7	13	670.2	2	173.7	77	4359.7
830526	0	0.0	38	2302.8	0	0.0	5	121.2	8	387.7	2	126.2	53	2937.9
830601	0	0.0	35	2379.8	0	0.0	6	404.0	7	279.7	4	395.1	52	3458.6
830603	1	144.0	17	1221.6	0	0.0	3	88.5	7	373.5	6	631.7	34	2459.3
830607	0	0.0	18	1308.0	0	0.0	4	177.4	3	94.5	1	6.0	26	1585.9
830609	1	75.2	12	814.9	0	0.0	5	316.8	7	327.7	3	377.2	28	1911.8
830614	0	0.0	10	695.0	0	0.0	5	125.2	6	230.6	5	736.8	26	1787.6
830621	0	0.0	2	194.8	0	0.0	9	130.5	8	332.2	6	685.1	25	1342.6
830623	0	0.0	3	245.7	0	0.0	16	342.7	10	687.6	4	744.4	33	2020.4
830628	1	115.9	1	64.3	0	0.0	12	172.2	3	262.0	0	0.0	17	614.4
830630	1	54.9	1	77.0	0	0.0	7	174.4	6	293.1	0	0.0	15	599.4
830706	1	2.0	2	178.6	0	0.0	4	28.5	5	401.1	3	4.5	15	614.7
830708	3	4.1	3	175.3	0	0.0	11	180.7	9	553.5	5	9.1	31	922.7
830712	0	0.0	2	181.6	0	0.0	7	107.2	12	667.8	1	1.4	22	958.0
830719	0	0.0	1	39.9	0	0.0	6	252.7	5	226.0	3	78.7	15	597.3
830721	1	52.6	1	86.5	1	1.3	15	68.1	6	345.0	1	133.9	25	687.4
830726	1	86.8	3	192.7	0	0.0	32	227.7	11	620.0	1	1.6	48	1128.8
830728	3	5.6	5	409.5	3	4.1	20	32.4	12	641.1	1	7.3	44	1100.0
830802	1	16.0	3	327.8	0	0.0	5	8.4	4	169.9	1	79.6	14	601.7
830804	2	25.0	2	63.3	1	1.3	28	257.1	18	797.0	0	0.0	51	1143.7
830811	5	124.1	13	848.7	0	0.0	99	235.0	17	746.7	1	6.7	135	1961.2
830816	4	101.4	9	606.5	0	0.0	50	117.1	13	474.6	0	0.0	76	1299.6
830818	0	0.0	10	872.7	0	0.0	21	140.5	12	543.6	0	0.0	43	1556.8
830823	4	246.5	5	263.6	0	0.0	17	182.2	10	456.3	1	1.3	37	1149.9
830825	1	14.6	9	446.4	0	0.0	36	172.3	3	96.7	0	0.0	49	730.0
830830	7	112.8	7	468.3	0	0.0	3	18.9	12	435.5	1	14.3	30	1049.8
830901	1	1.5	7	605.3	0	0.0	29	79.2	9	488.1	17	183.1	63	1357.2
830908	80	968.0	7	389.6	0	0.0	24	50.6	11	535.0	0	0.0	122	1943.2
830913	1	0.6	8	660.4	0	0.0	45	195.1	11	402.1	52	788.9	117	2047.1

TABLE 6.1.2. THE NUMBER AND WEIGHT (GMS.) OF INDIVIDUALS FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED AT NORTH ANNA POWER STATION BY SAMPLE DATE, 1978- 1983. VALUES REPRESENT TOTALS OVER A 24-HOUR PERIOD. ABBREVIATIONS ARE: DC - DOROSOMA CEPEDIANUM, PN - POMOXIS NIGROMACULATUS, PF - PERCA FLAVESCNS, LMA -LEPOMIS MACROCHIRUS, MA - MORONE AMERICANA, OT - OTHER. THE SUFFIXES ARE T - NUMBER AND W - WEIGHT.

DATE	DCT	DCW	PNT	PNW	PFT	PFW	LMAT	LMAW	MAT	MAW	OTT	OTW	TFISH	TWT
830915	1	2.0	18	1176.8	0	0.0	81	245.7	15	572	537	5628.7	652	7624.8
830920	1	9.6	19	932.0	0	0.0	82	124.8	11	357	1	2.4	114	1426.3
830922	2	5.9	18	716.9	0	0.0	64	114.9	9	418	7	262.7	100	1518.9
830927	6	15.5	25	1209.5	0	0.0	52	207.0	7	384	11	366.7	101	2182.8
830929	8	14.8	34	1949.8	0	0.0	48	109.1	12	419	7	83.9	109	2577.0
831006	6	6.2	8	441.8	1	14.4	17	35.5	4	225	12	98.8	48	822.1
831007	1	5.6	3	184.6	0	0.0	4	37.0	0	0	2	1.6	10	228.8
831011	1	1.5	10	804.8	0	0.0	31	85.8	5	196	7	126.2	54	1214.7
831013	14	75.1	17	1740.4	0	0.0	23	48.6	8	518	1	1.4	63	2383.8
831019	2	4.1	20	1198.7	0	0.0	17	82.9	11	417	9	268.5	59	1971.0
831021	2	3.3	33	1943.2	0	0.0	46	105.5	14	457	51	375.7	146	2884.4
831025	2	4.7	27	1531.6	0	0.0	42	264.2	15	601	28	550.6	114	2952.2
831027	6	12.5	32	2367.4	0	0.0	15	110.8	3	102	55	752.4	111	3344.8
831103	9	24.2	25	1297.2	0	0.0	25	79.6	11	391	69	1106.8	139	2899.2
831108	16	39.1	19	1285.1	0	0.0	34	58.9	9	334	130	1963.9	208	3681.2
831110	6	11.4	15	904.2	0	0.0	24	341.1	8	337	61	778.9	114	2372.7
831115	94	1044.9	11	563.1	0	0.0	6	17.7	10	391	3	42.0	124	2058.6
831117	12	22.8	16	787.2	0	0.0	11	31.0	15	434	41	581.3	95	1856.1
831121	27	46.9	3	124.9	0	0.0	42	100.5	27	849	24	304.8	123	1425.8
831123	14	18.9	4	161.2	0	0.0	17	31.7	19	658	33	420.9	87	1291.2
831201	80	128.8	4	155.4	1	16.7	8	22.4	8	386	181	1460.5	282	2169.9
831206	108	191.6	5	172.0	0	0.0	3	8.6	27	1038	501	3727.8	644	5138.3
831208	84	161.4	9	429.0	0	0.0	8	14.7	13	570	357	3199.0	471	4374.6
831213	119	229.1	15	623.6	0	0.0	4	8.2	17	797	379	2896.7	534	4554.5
831215	70	152.1	17	755.1	1	20.5	9	30.2	18	649	391	3487.4	506	5094.7
831220	32	62.2	1	44.7	0	0.0	7	25.7	2	62	57	969.6	99	1164.0
831222	20	40.2	3	111.2	0	0.0	2	15.3	8	344	172	2095.3	205	2606.1
TOTAL	640	1211.7	38054	1844657	38194	672065.7	9504	108377.5	3421	153883	152464	2920373	242277	5700567.6

TABLE 6.1.3. ESTIMATED NUMBERS AND WEIGHTS, AVERAGE LENGTH AND AVERAGE WEIGHT FOR SELECTED FISH SPECIES AND TOTALS FOR OTHER SPECIES IMPINGED DURING 1978-1983 AT NORTH ANNA POWER STATION.

SPECIES	1978				1979			
	ESTIMATED CATCH (X1000)	ESTIMATED WEIGHT (KG)	AVERAGE LENGTH(MM)	AVERAGE WEIGHT (G)	ESTIMATED CATCH (X1000)	ESTIMATED WEIGHT (KG)	AVERAGE LENGTH (MM)	AVERAGE WEIGHT (G)
DOROSOMA CEPEDIANUM	3.28	69.9	127	21	452.95	5257.7	124	12
LEPOMIS MACROCHIRUS	0.71	32.7	127	46	2.46	90.5	114	37
MORONE AMERICANA	0.03	1.6	127	45	1.22	72.0	156	59
PERCA FLAVESCENS	7.89	54.1	97	7	86.39	1450.0	121	17
POMOXIS NIGROMACULATUS	9.12	333.9	133	37	38.35	1806.8	151	47
OTHER	1.09	89.1	174	81	2.16	134.9	178	63
TOTAL	22.12	581.3	132	26	583.53	8811.9	136	15

SPECIES	1980				1981			
	ESTIMATED CATCH (X1000)	ESTIMATED WEIGHT (KG)	AVERAGE LENGTH (MM)	AVERAGE WEIGHT (G)	ESTIMATED CATCH (X1000)	ESTIMATED WEIGHT (KG)	AVERAGE LENGTH (MM)	AVERAGE WEIGHT (G)
DOROSOMA CEPEDIANUM	27.03	846.4	166	31	66.49	3771.2	203	57
LEPOMIS MACROCHIRUS	9.64	132.3	81	14	15.32	102.0	70	7
MORONE AMERICANA	0.68	26.5	131	39	2.45	109.3	155	45
PERCA FLAVESCENS	33.67	668.7	123	20	7.39	172.6	131	23
POMOXIS NIGROMACULATUS	36.77	1891.8	166	51	31.15	1634.5	176	52
OTHER	3.53	88.1	110	25	5.23	131.1	119	25
TOTAL	111.32	3653.8	140	33	128.03	5920.6	151	46

SPECIES	1982				1983			
	ESTIMATED CATCH (X1000)	ESTIMATED WEIGHT (KG)	AVERAGE LENGTH (MM)	AVERAGE WEIGHT (G)	ESTIMATED CATCH (X1000)	ESTIMATED WEIGHT (KG)	AVERAGE LENGTH (MM)	AVERAGE WEIGHT (G)
DOROSOMA CEPEDIANUM	19.59	914.6	172	47	17.16	200.7	119	12
LEPOMIS MACROCHIRUS	4.01	38.6	75	10	5.75	36.5	62	7
MORONE AMERICANA	5.17	238.4	162	46	4.08	164.9	150	40
PERCA FLAVESCENS	11.78	235.7	128	20	3.58	63.5	124	18
POMOXIS NIGROMACULATUS	24.59	1097.1	170	45	11.02	556.8	170	50
OTHER	1.40	65.5	142	46	3.99	39.5	87	10
TOTAL	66.55	2589.9	151	39	45.59	1061.9	121	24

TABLE 6.1.4. MEAN SEASONAL IMPINGEMENT ESTIMATES BY SPECIES, 1978-1983.

SPECIES	WINTER	SPRING	SUMMER	FALL	TOTAL
ACANTHARCHUS POMOTIS	3.29	6.68		4.00	13.97
ALOSA AESTIVALIS	1.99	3.30	3.33	26.05	34.67
ANGUILLA ROSTRATA	52.23	0.66		0.67	53.56
APHREDODERUS SAYANUS		0.66			0.66
CATOSTOMUS COMMERSONI			0.67		0.67
DOROSOMA CEPEDIANUM	83959.51	9582.85	684.58	3524.41	97751.34
DOROSOMA PETENENSE		0.66	15.33	449.78	465.77
ERIMYZON OBLONGUS		0.72	0.67		1.39
ESOX NIGER	2.64	0.66			3.30
ETHEOSTOMA OLMSTEDI	0.65	0.66			1.31
EXOGLOSSUM MAXILLINGUA		0.66			0.66
FUNDULUS HETEROCLITUS	1.30	0.66			1.96
ICTALURUS CATUS			0.67		0.67
ICTALURUS NATALIS		2.86			2.86
ICTALURUS NEBULOSUS	37.83	217.00	81.83	11.34	348.00
ICTALURUS PUNCTATUS	5.90	7.35	7.29	1.31	21.84
LEPOMIS AURITUS	0.65	5.40	9.92	5.32	21.30
LEPOMIS GIBBOSUS	3.97	14.00	7.32	22.67	47.97
LEPOMIS GULOSUS	4.57	20.78	5.86	4.13	35.34
LEPOMIS MACROCHIRUS	638.95	1850.60	1599.86	2226.15	6315.56
LEPOMIS MICROLOPHUS	1.96	2.64	0.64	0.67	5.90
MICROPTERUS SALMOIDES	3.32	22.63	31.81	15.90	73.66
MORONE AMERICANA	644.05	766.79	370.80	490.05	2271.69
MORONE SAXATILIS	683.03	80.71	5.92	900.87	1670.53
NOTEMIGONUS CRYSOLEUCAS	27.57	31.58	2.00	18.96	80.11
NOTROPIS ANALOSTANUS		2.04	1.33		3.37
NOTROPIS CORNUTUS		1.32			1.32
PERCA FLAVESCENS	22414.45	2658.30	21.75	22.17	25116.67
PETROMYZON MARINUS	3.26	1.98			5.24
PHOXINUS OREAS	0.65				0.65
PIMEPHALES NOTATUS	1.36				1.36
POMOXIS NIGROMACULATUS	11305.64	5854.07	1431.92	6576.84	25168.48
STIZOSTEDION VITREUM	0.65	0.66			1.31
UMBRA PYGMAEA	0.65				0.65
TOTAL	119800	21138.88	4283.50	14301.28	159524

TABLE 6.1.5. LENGTH-FREQUENCIES AND PERCENT OF DOROSOMA CEPEDIANUM IMPINGED AT NORTH ANNA POWER STATION, 1978-1983. LENGTHS (T.L.) ARE IN MM. THIS TABLE REFLECTS ONLY THOSE FISH ACTUALLY MEASURED.

LENGTH	1978	%	1979	%	1980	%	1981	%	1982	%	1983	%	TOTAL
_0	18	2.9	1	0.0	0	0.0	1	0.0	0	0.0	2	0.1	22
‾50	93	15.1	93	2.7	230	9.2	57	1.7	84	4.2	698	41.0	1255
‾100	333	54.1	3027	89.1	862	34.6	168	5.1	665	32.9	761	44.7	5816
‾150	122	19.8	95	2.8	350	14.1	771	23.4	704	34.9	76	4.5	2118
‾200	49	8.0	171	5.0	1015	40.8	2214	67.2	461	22.8	153	9.0	4063
GE250	0	0.0	11	0.3	32	1.3	82	2.5	105	5.2	14	0.8	244
TOTAL	615		3398		2489		3293		2019		1704		13518

TABLE 6.1.6. LENGTH-FREQUENCIES AND PERCENT OF POMOXIS NIGROMACUATUS IMPINGED AT NORTH ANNA POWER STATION, 1978-1983. LENGTHS (T.L.) ARE IN MM. THIS TABLE REFLECTS ONLY THOSE FISH ACTUALLY MEASURED.

LENGTH	1978	%	1979	%	1980	%	1981	%	1982	%	1983	%	TOTAL
_0	20	1.1	0	0.0	3	0.1	1	0.0	1	0.0	1	0.1	26
‾50	564	31.2	743	20.0	381	9.5	213	5.7	33	1.4	22	1.3	1956
‾100	568	31.4	952	25.6	744	18.5	140	3.8	144	5.9	129	7.9	2677
‾150	428	23.7	1432	38.5	2117	52.7	2865	76.9	2113	87.2	1334	81.7	10289
‾200	226	12.5	591	15.9	771	19.2	508	13.6	131	5.4	144	8.8	2371
GE250	3	0.2	2	0.1	2	0.0	1	0.0	0	0.0	2	0.1	10
TOTAL	1809		3720		4018		3728		2422		1632		17329

TABLE 6.1.7. LENGTH-FREQUENCIES AND PERCENT OF PERCA FLAVESCENS IMPINGED AT NORTH ANNA POWER STATION, 1978-1983. LENGTHS (T.L.) ARE IN MM. THIS TABLE REFLECTS ONLY THOSE FISH ACTUALLY MEASURED.

LENGTH	1978	%	1979	%	1980	%	1981	%	1982	%	1983	%	TOTAL
_0	7	2.5	1	0.1	1	0.1	1	0.1	0	0.0	0	0.0	10
‾50	186	66.4	557	34.7	246	20.9	127	13.3	154	14.8	109	19.1	1379
‾100	61	21.8	730	45.5	783	66.5	705	74.1	749	72.0	370	64.7	3398
‾150	20	7.1	245	15.3	143	12.1	113	11.9	134	12.9	92	16.1	747
‾200	2	0.7	53	3.3	3	0.3	5	0.5	3	0.3	0	0.0	66
GE250	4	1.4	19	1.2	1	0.1	1	0.1	0	0.0	1	0.2	26
TOTAL	280		1605		1177		952		1040		572		5626

TABLE 6.1.8. LENGTH-FREQUENCIES AND PERCENT OF LEPOMIS MACROCHIRUS IMPINGED AT NORTH ANNA POWER STATION, 1978-1983. LENGTHS (T.L.) ARE IN MM. THIS TABLE REFLECTS ONLY THOSE FISH ACTUALLY MEASURED.

LENGTH	1978	%	1979	%	1980	%	1981	%	1982	%	1983	%	TOTAL
_0	24	14.7	72	11.5	403	19.5	535	21.2	162	16.1	513	38.6	1709
‾50	23	14.1	176	28.1	1094	53.0	1622	64.4	641	63.8	685	51.6	4241
‾100	48	29.4	180	28.8	380	18.4	285	11.3	172	17.1	92	6.9	1157
‾150	67	41.1	195	31.2	186	9.0	73	2.9	29	2.9	38	2.9	588
‾200	1	0.6	3	0.5	3	0.1	3	0.1	1	0.1	0	0.0	11
GE250	0	0.0	0	0.0	0	0.0	1	0.0	0	0.0	0	0.0	1
TOTAL	163		626		2066		2519		1005		1328		7707

TABLE 6.1.9. LENGTH-FREQUENCIES AND PERCENT OF MORONE AMERICANA IMPINGED AT NORTH ANNA POWER STATION, 1978-1983. LENGTHS (T.L.) ARE IN MM. THIS TABLE REFLECTS ONLY THOSE FISH ACTUALLY MEASURED.

LENGTH	1978	%	1979	%	1980	%	1981	%	1982	%	1983	%	TOTAL
_0	0	0.0	1	0.3	2	1.1	0	0.0	4	0.3	3	0.3	10
‾50	3	37.5	37	11.9	68	39.1	88	14.4	49	4.0	67	6.9	312
‾100	2	25.0	85	27.3	27	15.5	118	19.2	272	22.2	361	37.4	865
‾150	2	25.0	140	45.0	53	30.5	357	58.2	826	67.5	499	51.7	1877
‾200	1	12.5	42	13.5	22	12.6	49	8.0	73	6.0	34	3.5	221
GE250	0	0.0	6	1.9	2	1.1	1	0.2	0	0.0	1	0.1	10
TOTAL	8		311		174		613		1224		965		3295

FIGURE 6.1.1 LENGTH-FREQUENCY DISTRIBUTION OF POMOXIS NIGROMACULATUS IMPINGED AT NORTH ANNA POWER STATION, 1978-1983.

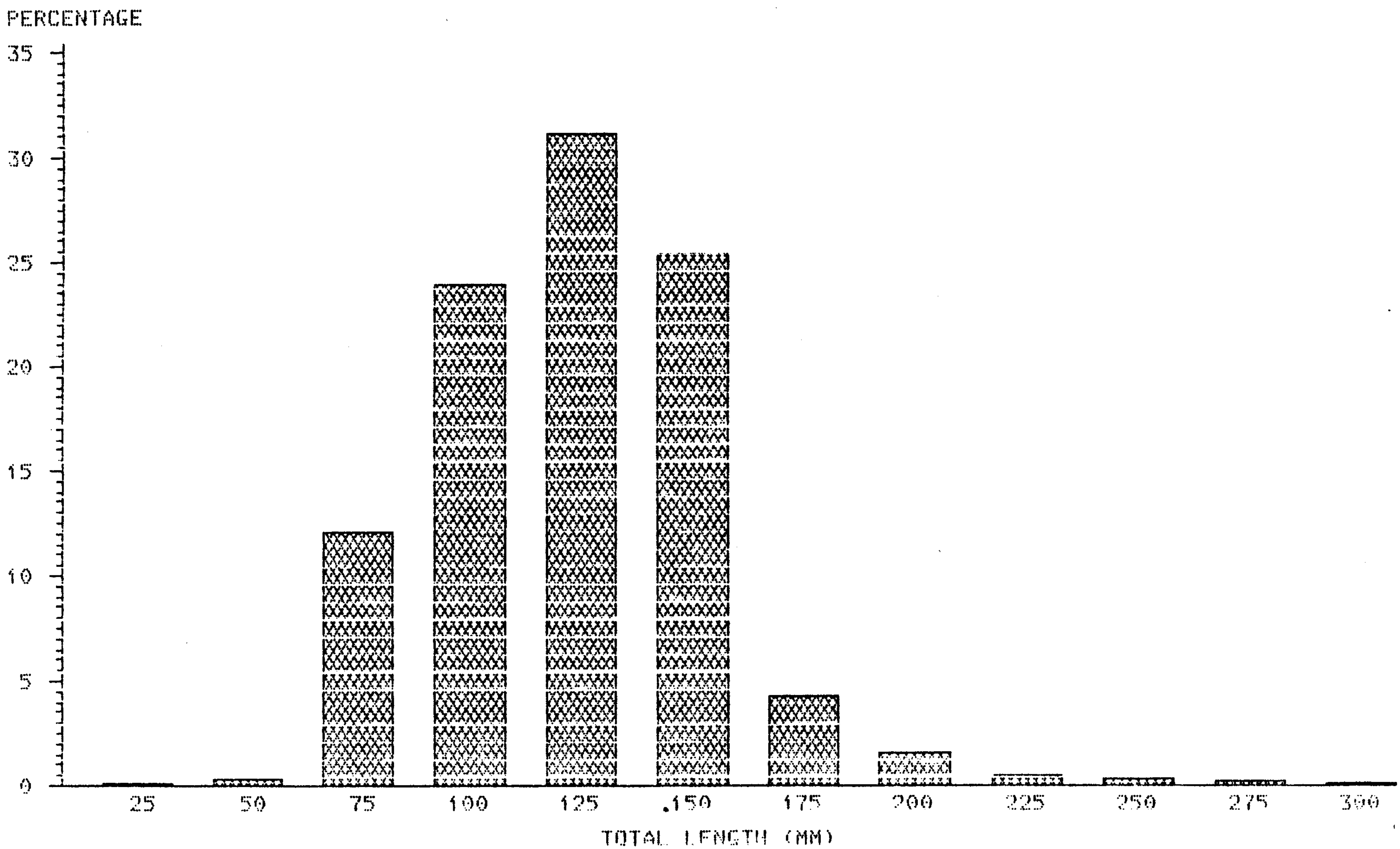


FIGURE 6.1.2 LENGTH-FREQUENCY DISTRIBUTION OF DOROSOMA CEPEDIANUM IMPINGED AT NORTH ANNA POWER STATION, 1978-1983.

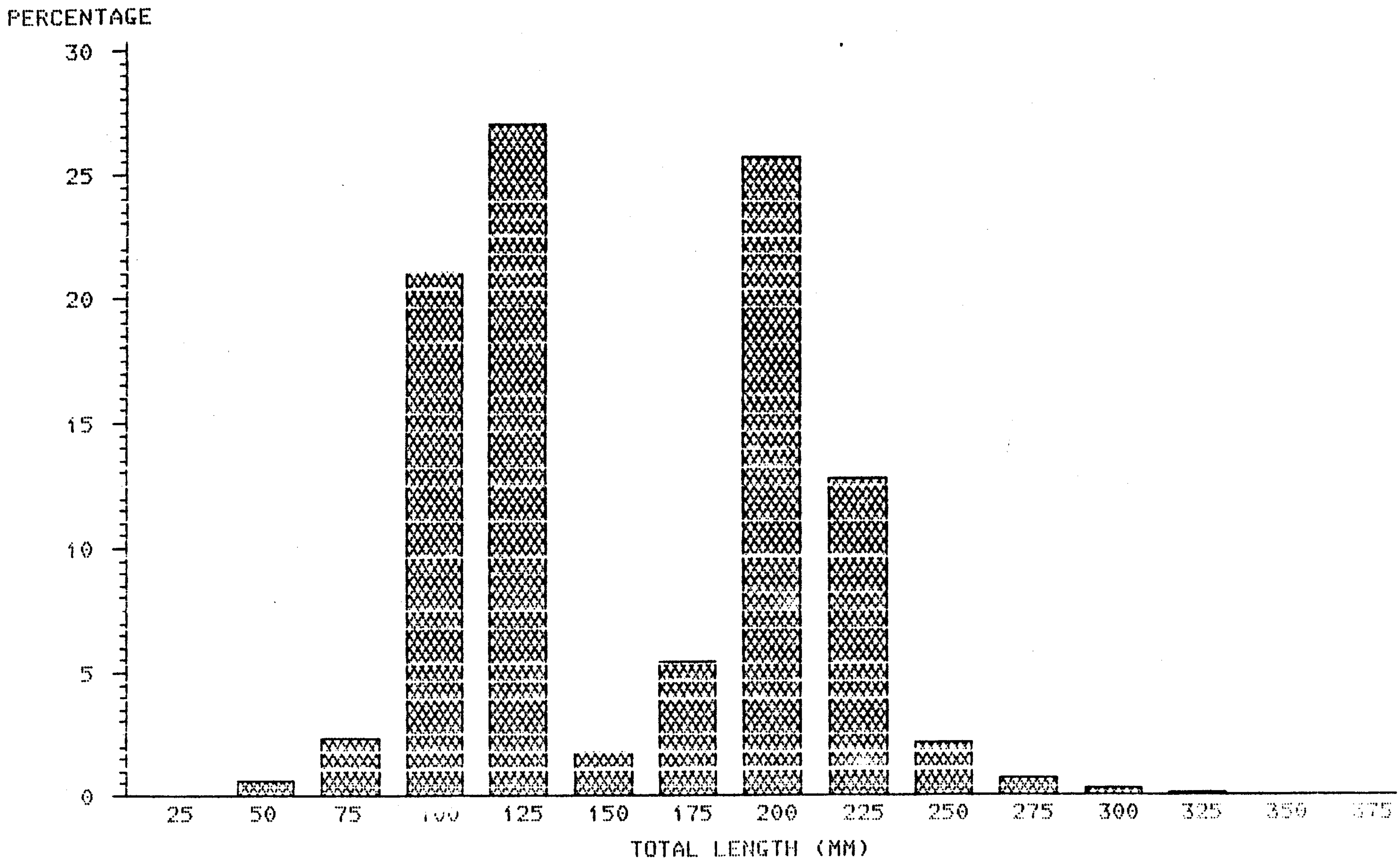


FIGURE 6.1.3 LENGTH-FREQUENCY DISTRIBUTION OF PERCA FLAVESCENS IMPINGED AT NORTH ANNA POWER STATION, 1978-1983.

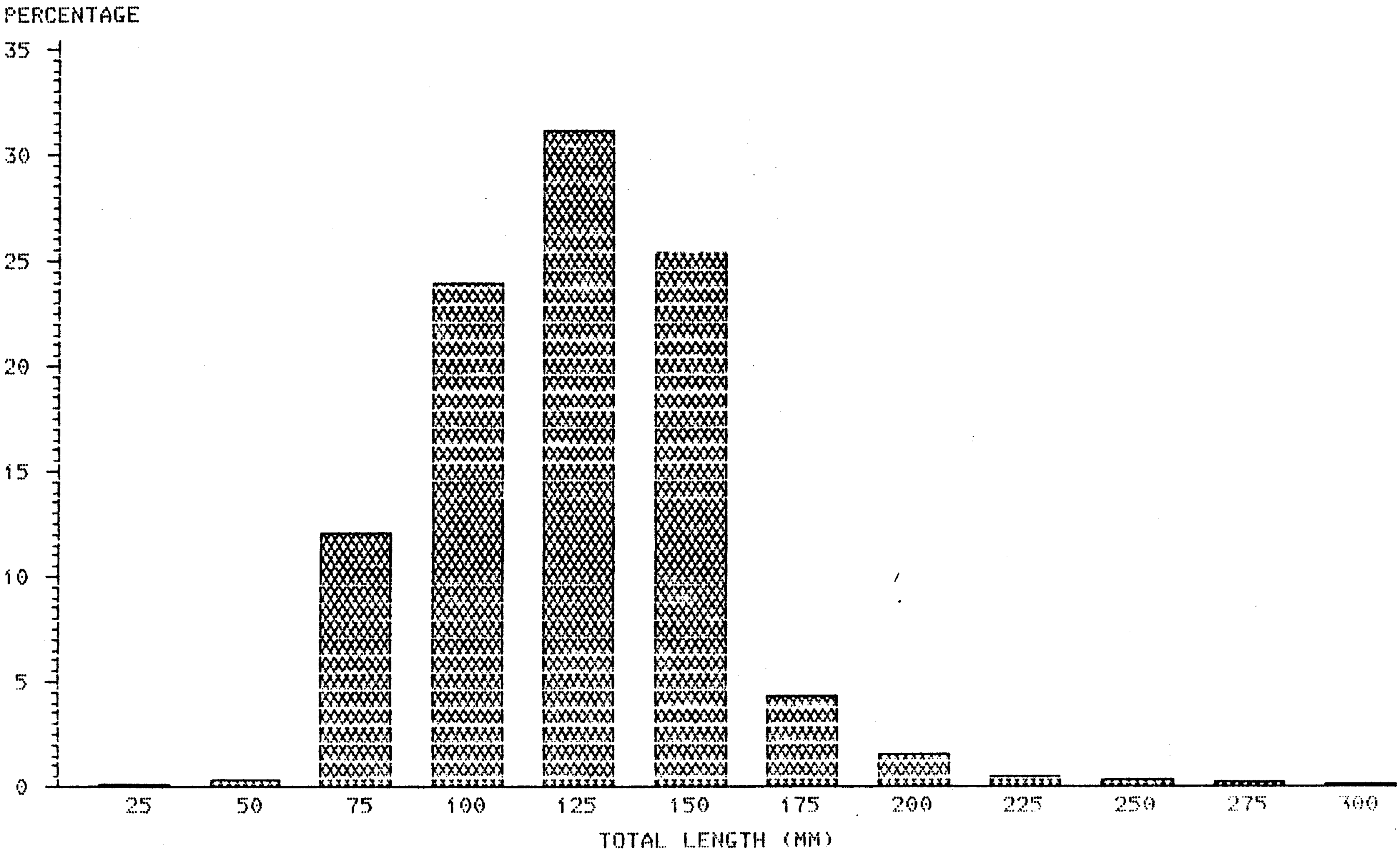


FIGURE 6.1.4 LENGTH-FREQUENCY DISTRIBUTION OF LEPOMIS MACROCHIRUS IMPINGED AT NORTH ANNA POWER STATION, 1978-1983.

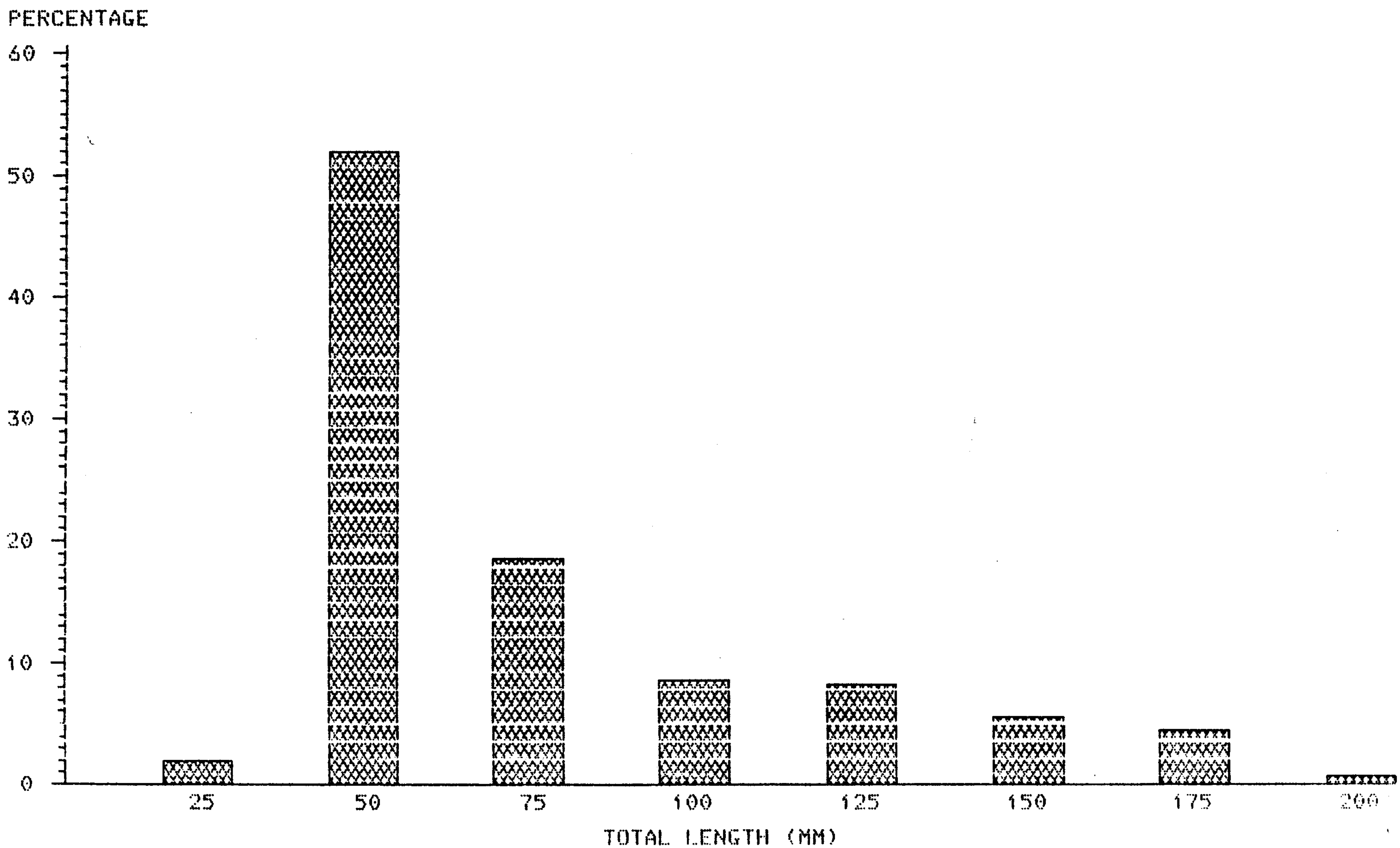
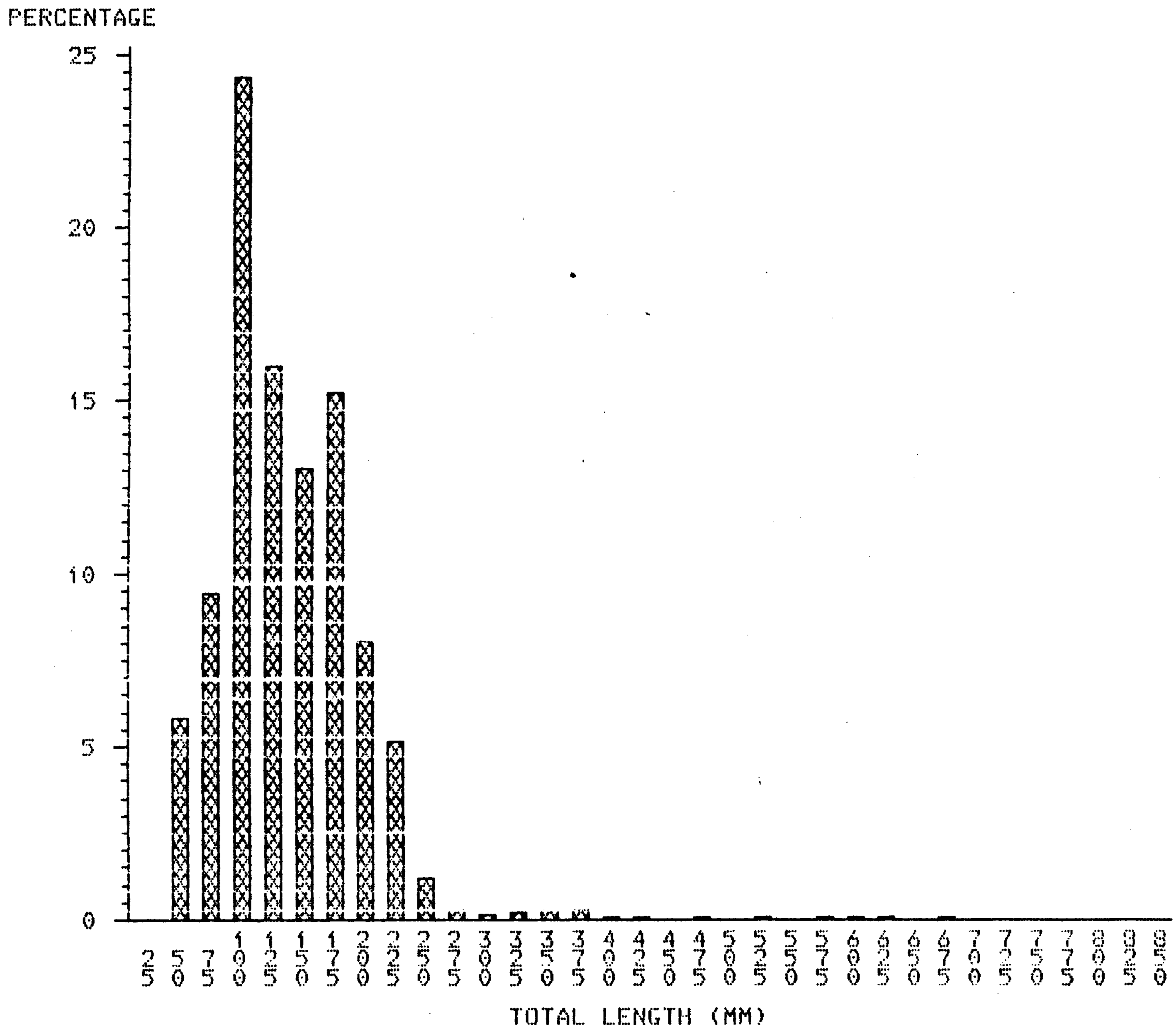


FIGURE 6.1.5 LENGTH-FREQUENCY DISTRIBUTION OF OTHER FISH IMPINGED AT NORTH ANNA POWER STATION, 1978-1983.



6.2 Entrainment

A total of 7908 fish larvae were collected in entrainment samples at North Anna Power Station from 1978-1983 (Table 6.2.1). The most abundant entrained larvae over all years were gizzard shad (65.7%) followed by white perch (15.0%), sunfishes, Lepomis spp. (13.3%), yellow perch (4.9%) and black crappie (1.0%). The channel catfish, Ictalurus punctatus, and largemouth bass, Micropterus salmoides, were each represented by only a singly collected individual. Sunfishes are considered in this report to represent several possible species. More sunfish and yellow perch larvae were collected in the first year (1978) than in subsequent years. Gizzard shad, however, were collected in relatively greater numbers in 1979 and 1981. White perch numbers have generally increased over the study period. Black crappie numbers are considered too low for any meaningful comparisons. With the exception of 1978, the changes in total numbers entrained from year to year are generally reflected in the number of gizzard shad, sunfishes and white perch collected. The percentage of the total larvae collected represented by gizzard shad has remained high and stable for each year, whereas the percentage of white perch has increased each year.

During each entrainment survey, the number of circulating water pumps (CWP), the sample volume, the water temperature and oxygen content were recorded (Table 6.2.2). Yellow perch was first to appear in all collecting years, generally in early April, when water temperatures approached 12°C. White perch appeared in April when temperatures approached 14°C and peaked in numbers by mid-May. Gizzard shad generally were first collected in late April to early May at water temperatures between 14°C and 18°C and peaked in numbers in mid-May to early June. Sunfishes were the last group to occur in samples (May-June) and were first collected when water temperatures rose to 19°C. Both gizzard shad and sunfish were collected in relatively fewer numbers in July.

Samples collected during the 6-hour intervals within a day generally showed that total numbers and percent vary considerably from 0600 hours to 1800 hours and were highest during the 2400-hour sample (Tables 6.2.3 and 6.2.4). Over all years and samples the percentage of fish larvae collected during the midnight sample was 43%. Gizzard shad and white perch collections were responsible for the higher numbers during the 2400-hour sample. The large number of larvae collected at night is probably a function of diurnal migration patterns or in part by net avoidance (Gasser 1976; Ecological Analysts 1977). Sunfishes were, on the contrary, generally collected more frequently during daylight hours and yellow perch numbers fluctuated during sample intervals.

Factors such as turbidity, temperature, larval size and gear type have been shown to influence distributional patterns (Edwards et al. 1977; Netch et al. 1971; Tuberville 1977; Leithiser et al. 1979; Cada and Loar 1982). Any combination of factors could cause a site specificity in larval distribution. The percent of total larvae collected at each sample depth varied from year to year and for each species (Table 6.2.5). Sunfishes, yellow perch and black crappie were collected primarily from surface samples; gizzard shad were collected primarily from middle and bottom depths; and white perch numbers were similar at all depths (Table 6.2.6). Over all species and all collection years the percentage of larvae collected from the surface was 33%, from the mid-depth (4 m) was 35% and from the bottom (8 m) was 32%.

No fish eggs were collected during the sample years 1978-1983. Most species of reproducing fish in Lake Anna produce demersal, adhesive eggs which significantly reduces potential entrainment (Lippson and Moran 1974).

The gizzard shad entrainment rate (numbers per CWP) has been declining since 1979 (Figure 6.2.1). There was a substantial increase in entrainment of this species from 1978 to 1979. The higher number of gizzard shad larvae collected in 1979 apparently resulted from a successful spawn that year. This is supported by rotenone data with the increase in standing crop estimates for adults and juveniles from 109.1 kg/ha in 1979 to 153.7 kg/ha in 1980 (Vepco 1983). Meteorologically, 1979 was similar to other sample years.

Entrainment rates for sunfishes have been constant since 1979 while white perch numbers have increased each year. The higher collection numbers of sunfishes in 1978 probably was a result of the initial withdrawal of the resident sunfish population within the intake cove. Sunfish adults do not migrate large distances over short time periods within a lake as gizzard shad or white perch may. The declining entrainment rate for sunfish may be a result of limited adult recruitment for spawning within the intake cove. The increase in white perch larvae collected from 1978-1983 is supported by increasing fish standing estimates based upon cove rotenone samples (Vepco 1983, 1984).

To determine the total estimated larvae entrained over time, daily entrainment estimates were prepared treating depths as strata. Stratum weights were equal and the finite correction factor was ignored (Cochran 1963). Daily density values (larvae/1000 m^3) were multiplied by the average volume of intake water pumped that sample day. Period estimates were computed using daily estimates and the number of days in each period. Variances for period estimates were taken as a weighted average of daily variances. Totaling period estimates by species result in estimates of total larvae entrained by sample year (Table 6.2.7). Total estimated fish larvae entrained ranged from 8.4×10^7 in 1982 to 2.5×10^8 in 1981 (Figure 6.2.2). Also during entrainment sampling periods in 1982 only an average of 3.2 circulating water pumps were operating, whereas an average of 6.4 pumps were operating in 1981.

Out of an estimated total of 8.9×10^8 larvae entrained from 1978-1983, gizzard shad represented 65% (5.8×10^8) of the total. By comparison, in Lake Sangchris, Illinois, 85% of the total fish entrained at the Kincaid Generating Station were gizzard shad (Porak and Tranquilli 1981). An estimated total of 2.1×10^8 shad and 1.7×10^6 sunfishes were entrained there in 1976. The average estimated number entrained at North Anna per year for gizzard shad was 9.6×10^7, for white perch was 2.3×10^6, for sunfishes was 2.1×10^6, for yellow perch was 6.8×10^5 and for black crappie was 1.7×10^5 (Table 6.2.7).

While the total estimated larvae entrained per year has varied from 1978-1983 (Figure 6.2.2), primarily as a result of fluctuations in adult fish standing crops and circulating water pump operation, the total number entrained per pump, or entrainment rate, generally has been declining since 1979 (Figure 6.2.1). Standing crop estimates (kg/ha) in Lake Anna for gizzard shad have been declining from 1980-1982, with an increase in 1983, while white perch estimates have steadily increased from year to year (Vepco 1983, 1984).

Standing crop estimates for yellow perch and crappie have been declining for the past several years, but standing crop estimates for bluegill, the most abundant sunfish in Lake Anna, have been constant over the sample years.

TABLE 6.2.1. THE TOTAL CATCH AND PERCENT OF FISH LARVAE ENTRAINED AT NORTH ANNA POWER STATION DURING 1978-1983.

	CATCH (%)						
	1978	1979	1980	1981	1982	1983	TOTAL
OSTEICHTHYES							
CLUPEIDAE - HERRINGS							
DOROSOMA CEPEDIANUM - GIZZARD SHAD	514(43.2)	1397(87.9)	941(73.6)	1126(64.2)	471(51.1)	733(62.3)	5182(65.5)
ICTALURIDAE - BULLHEAD CATFISHES							
ICTALURUS PUNCTATUS - CHANNEL CATFISH	.(.)	.(.)	.(.)	.(.)	.(.)	1(0.1)	1(0.0)
PERCICHTHYIDAE - TEMPERATE BASSES							
MORONE AMERICANA - WHITE PERCH	3(0.3)	56(3.5)	91(7.1)	391(22.3)	293(31.8)	361(30.7)	1195(15.1)
CENTRARCHIDAE - SUNFISHES							
LEPOMIS SPP. - SUNFISH	531(44.6)	112(7.0)	161(12.6)	117(6.7)	114(12.4)	28(2.4)	1063(13.4)
MICROPTERUS SALMOIDES - LARGEMOUTH BASS	1(0.1)	.(.)	.(.)	.(.)	.(.)	.(.)	1(0.0)
POMOXIS NIGROMACULATUS - BLACK CRAPPIE	12(1.0)	6(0.4)	13(1.0)	16(0.9)	6(0.7)	29(2.5)	82(1.0)
PERCIDAE - PERCHES							
PERCA FLAVESCENS - YELLOW PERCH	130(10.9)	18(1.1)	72(5.6)	103(5.9)	37(4.0)	24(2.0)	384(4.9)
TOTAL	1191	1589	1278	1753	921	1176	7908

TABLE 6.2.2 LARVAE ENTRAINED DURING SAMPLE DATES AT NORTH ANNA POWER STATION DURING 1978-1983. DISSOLVED OXYGEN AND TEMPERATURE VALUES ARE AVERAGES OF SURFACE SAMPLES.

DATE	SPECIES	CATCH	VOLUME (X1000)	AVERAGE PUMPS	AVERAGE FISH PER CUBIC METER	TEMPERATURE	DISSOLVED OXYGEN
780411	PERCA FLAVESCENS	7	5193	4.0	20.2	12.4	10.4
780418	PERCA FLAVESCENS	99	5193	4.0	251.9	13.1	10.4
780425	PERCA FLAVESCENS	4	9088	7.0	8.4	13.5	9.9
780502	PERCA FLAVESCENS	1	5193	4.0	2.6	13.7	10.2
780509	PERCA FLAVESCENS	8	5193	4.0	22.2	15.7	10.2
	MORONE AMERICANA	1	5139	4.0	2.8	15.7	10.2
780516	POMOXIS NIGROMACULATUS	2	7790	6.0	8.5	17.4	9.9
	DOROSOMA CEPEDIANUM	1	7844	6.0	3.0	17.4	9.9
780520	NO LARVAE	.	.	.	.	.	.
780523	DOROSOMA CEPEDIANUM	54	5193	4.0	189.7	22.2	10.0
	PERCA FLAVESCENS	10	5193	4.0	35.8	22.2	10.0
	POMOXIS NIGROMACULATUS	5	5193	4.0	19.6	22.2	10.0
780601	DOROSOMA CEPEDIANUM	169	7790	6.0	379.5	25.4	8.9
	POMOXIS NIGROMACULATUS	4	7790	6.0	8.7	25.4	8.9
	MORONE AMERICANA	2	7790	6.0	4.5	25.4	8.9
	LEPOMIS SP.	1	7790	6.0	2.0	25.4	8.9
	PERCA FLAVESCENS	1	7790	6.0	2.0	25.4	8.9
780606	DOROSOMA CEPEDIANUM	208	7790	6.0	433.5	24.8	8.0
	LEPOMIS SP.	33	7790	6.0	73.3	24.8	8.0
	MICROPTERUS SALMOIDES	1	7790	6.0	2.5	24.8	8.0
	POMOXIS NIGROMACULATUS	1	7790	6.0	1.9	24.8	8.0
780613	LEPOMIS SP.	70	7790	6.0	149.9	24.9	7.5
	DOROSOMA CEPEDIANUM	57	7790	6.0	119.9	24.9	7.5
780620	LEPOMIS SP.	105	5193	4.0	268.2	26.2	8.3
	DOROSOMA CEPEDIANUM	9	5193	4.0	19.3	26.2	8.3
780627	LEPOMIS SP.	91	7790	6.0	200.3	27.3	7.9
	DOROSOMA CEPEDIANUM	10	7790	6.0	19.4	27.3	7.9
780706	LEPOMIS SP.	63	7790	6.0	156.9	26.0	7.1
	DOROSOMA CEPEDIANUM	4	7790	6.0	8.2	26.0	7.1
780711	LEPOMIS SP.	108	7790	6.0	256.7	26.7	7.7
780718	LEPOMIS SP.	21	7790	6.0	60.1	27.1	8.0
	DOROSOMA CEPEDIANUM	2	7790	6.0	5.0	27.1	8.0

TABLE 6.2.2 LARVAE ENTRAINED DURING SAMPLE DATES AT NORTH ANNA POWER STATION DURING 1978-1983. DISSOLVED OXYGEN AND TEMPERATURE VALUES ARE AVERAGES OF SURFACE SAMPLES.

DATE	SPECIES	CATCH	VOLUME (X1000)	AVERAGE PUMPS	AVERAGE FISH PER CUBIC METER	TEMPERATURE	DISSOLVED OXYGEN
780725	LEPOMIS SP.	39	8763	6.8	88.0	29.3	7.8
790301	NO LARVAE	.	3895	3.0	.	3.3	11.7
790308	NO LARVAE	.	3895	3.0	.	4.9	11.5
790315	NO LARVAE	.	3895	3.0	.	6.0	11.9
790322	NO LARVAE	.	3895	3.0	.	9.7	12.7
790329	NO LARVAE	.	3895	3.0	.	10.1	11.6
790411	PERCA FLAVESCENS	16	5193	4.0	48.5	12.6	11.0
790419	MORONE AMERICANA	1	2597	2.0	3.5	14.0	10.1
	PERCA FLAVESCENS	1	2597	2.0	3.5	14.0	10.1
790426	MORONE AMERICANA	1	5193	4.0	2.9	16.8	10.2
790503	MORONE AMERICANA	3	4674	3.6	8.5	17.4	10.2
	DOROSOMA CEPEDIANUM	1	4652	3.6	2.4	17.4	10.2
	POMOXIS NIGROMACULATUS	1	4674	3.6	3.2	17.4	10.2
790510	DOROSOMA CEPEDIANUM	38	7790	6.0	97.6	21.6	9.6
	MORONE AMERICANA	19	7790	6.0	47.1	21.6	9.6
	POMOXIS NIGROMACULATUS	2	7790	6.0	5.9	21.6	9.6
	PERCA FLAVESCENS	1	7790	6.0	3.3	21.6	9.6
790517	DOROSOMA CEPEDIANUM	330	5193	4.0	870.7	21.4	8.8
	MORONE AMERICANA	10	5193	4.0	25.8	21.4	8.8
790524	DOROSOMA CEPEDIANUM	167	5193	4.0	407.2	21.4	8.5
	MORONE AMERICANA	5	5193	4.0	12.2	21.4	8.5
790531	DOROSOMA CEPEDIANUM	265	6491	5.0	622.2	22.5	8.8
	MORONE AMERICANA	17	6491	5.0	42.9	22.5	8.8
	LEPOMIS SP.	2	6491	5.0	5.0	22.5	8.8
	POMOXIS NIGROMACULATUS	2	6491	5.0	4.6	22.5	8.8
790607	DOROSOMA CEPEDIANUM	223	3895	3.0	573.3	24.4	8.8
	LEPOMIS SP.	6	3895	3.0	17.1	24.4	8.8
790614	DOROSOMA CEPEDIANUM	199	5193	4.0	460.1	24.3	8.5
	LEPOMIS SP.	57	5193	4.0	157.1	24.3	8.5
	POMOXIS NIGROMACULATUS	1	5193	4.0	2.9	24.3	8.5
790621	DOROSOMA CEPEDIANUM	81	5193	4.0	204.0	23.3	8.3
	LEPOMIS SP.	2	5193	4.0	4.9	23.3	8.3

TABLE 6.2.2 LARVAE ENTRAINED DURING SAMPLE DATES AT NORTH ANNA POWER STATION DURING 1978-1983. DISSOLVED OXYGEN AND TEMPERATURE VALUES ARE AVERAGES OF SURFACE SAMPLES.

DATE	SPECIES	CATCH	VOLUME (X1000)	AVERAGE PUMPS	AVERAGE FISH PER CUBIC METER	TEMPERATURE	DISSOLVED OXYGEN
790628	DOROSOMA CEPEDIANUM	53	5193	4.0	121.2	23.9	8.2
	LEPOMIS SP.	7	5193	4.0	18.8	23.9	8.2
790705	DOROSOMA CEPEDIANUM	10	5193	4.0	24.6	23.9	7.7
	LEPOMIS SP.	10	5193	4.0	25.8	23.9	7.7
790712	DOROSOMA CEPEDIANUM	11	6491	5.0	25.3	27.0	8.2
	LEPOMIS SP.	8	6491	5.0	19.8	27.0	8.2
790719	DOROSOMA CEPEDIANUM	18	5193	4.0	45.6	28.0	8.0
	LEPOMIS SP.	13	5193	4.0	32.6	28.0	8.0
790727	LEPOMIS SP.	7	5193	4.0	17.9	27.6	7.9
	DOROSOMA CEPEDIANUM	1	5193	4.0	2.4	27.6	7.9
800306	NO LARVAE	.	6491	5.0	.	4.1	12.8
800313	NO LARVAE	.	6491	5.0	.	5.5	12.4
800320	NO LARVAE	.	6491	5.0	.	7.7	12.4
800327	NO LARVAE	.	3895	3.0	.	9.4	11.5
800402	NO LARVAE	.	3895	3.0	.	11.0	11.4
800410	PERCA FLAVESCENS	47	3895	3.0	127.7	13.5	10.7
800417	PERCA FLAVESCENS	22	3895	3.0	58.7	13.2	10.0
	MORONE AMERICANA	1	3895	3.0	2.3	13.2	10.0
800424	MORONE AMERICANA	5	3895	3.0	17.0	17.0	10.0
	PERCA FLAVESCENS	3	3895	3.0	8.0	17.0	10.0
800501	MORONE AMERICANA	16	6491	5.0	40.2	15.9	9.8
	DOROSOMA CEPEDIANUM	4	6491	5.0	10.4	15.9	9.8
800508	DOROSOMA CEPEDIANUM	20	7790	6.0	43.6	19.0	9.3
	MORONE AMERICANA	19	7790	6.0	40.7	19.0	9.3
	POMOXIS NIGROMACULATUS	2	7790	6.0	4.3	19.0	9.3
800515	DOROSOMA CEPEDIANUM	79	7790	6.0	169.7	20.2	9.3
	MORONE AMERICANA	14	7790	6.0	31.3	20.2	9.3
	POMOXIS NIGROMACULATUS	4	7790	6.0	9.0	20.2	9.3
800522	DOROSOMA CEPEDIANUM	132	7790	6.0	288.8	22.2	9.0
	MORONE AMERICANA	19	7790	6.0	41.8	22.2	9.0

TABLE 6.2.2 LARVAE ENTRAINED DURING SAMPLE DATES AT NORTH ANNA POWER STATION DURING 1978-1983. DISSOLVED OXYGEN AND TEMPERATURE VALUES ARE AVERAGES OF SURFACE SAMPLES.

DATE	SPECIES	CATCH	VOLUME (X1000)	AVERAGE PUMPS	AVERAGE FISH PER CUBIC METER	TEMPERATURE	DISSOLVED OXYGEN
800529	DOROSOMA CEPEDIANUM	217	3895	3.0	580.6	23.9	9.1
	LEPOMIS SP.	7	3895	3.0	19.6	23.9	9.1
	MORONE AMERICANA	7	3895	3.0	18.6	23.9	9.1
	POMOXIS NIGROMACULATUS	4	3895	3.0	11.6	23.9	9.1
800605	DOROSOMA CEPEDIANUM	207	7790	6.0	409.3	24.4	8.9
	LEPOMIS SP.	41	7790	6.0	85.1	24.4	8.9
	MORONE AMERICANA	7	7790	6.0	13.5	24.4	8.9
	POMOXIS NIGROMACULATUS	2	7790	6.0	4.7	24.4	8.9
800612	DOROSOMA CEPEDIANUM	162	9088	7.0	320.4	23.5	8.5
	LEPOMIS SP.	34	9088	7.0	67.7	23.5	8.5
	MORONE AMERICANA	2	9088	7.0	3.7	23.5	8.5
800619	DOROSOMA CEPEDIANUM	65	9088	7.0	138.1	24.1	7.8
	LEPOMIS SP.	7	9088	7.0	16.5	24.1	7.8
	MORONE AMERICANA	1	9088	7.0	1.8	24.1	7.8
800626	LEPOMIS SP.	21	9088	7.0	43.1	25.0	7.8
	DOROSOMA CEPEDIANUM	18	9088	7.0	33.3	25.0	7.8
800702	DOROSOMA CEPEDIANUM	30	9737	7.5	61.7	26.4	7.3
	LEPOMIS SP.	19	9737	7.5	42.7	26.4	7.3
	POMOXIS NIGROMACULATUS	1	9737	7.5	2.6	26.4	7.3
800710	LEPOMIS SP.	17	10386	8.0	39.3	26.9	7.0
	DOROSOMA CEPEDIANUM	5	10386	8.0	9.3	26.9	7.0
800717	DOROSOMA CEPEDIANUM	2	9088	7.0	4.5	28.9	7.4
	LEPOMIS SP.	2	9088	7.0	5.4	28.9	7.4
800724	LEPOMIS SP.	8	9088	7.0	17.5	28.9	7.5
800731	LEPOMIS SP.	5	9088	7.0	11.9	29.5	7.6
810305	NO LARVAE	.	3895	3.0	.	6.7	11.9
810312	NO LARVAE	.	3895	3.0	.	7.2	11.6
810319	NO LARVAE	.	3895	3.0	.	7.0	11.3
810326	NO LARVAE	.	6816	5.3	.	7.5	11.4
810402	PERCA FLAVESCENS	19	9088	7.0	43.4	12.1	10.9
810409	PERCA FLAVESCENS	33	10386	8.0	69.5	13.0	10.3

TABLE 6.2.2 LARVAE ENTRAINED DURING SAMPLE DATES AT NORTH ANNA POWER STATION DURING 1978-1983. DISSOLVED OXYGEN AND TEMPERATURE VALUES ARE AVERAGES OF SURFACE SAMPLES.

DATE	SPECIES	CATCH	VOLUME (X1000)	AVERAGE PUMPS	AVERAGE FISH PER CUBIC METER	TEMPERATURE	DISSOLVED OXYGEN
810415	PERCA FLAVESCENS	50	9088	7.0	101.3	13.9	10.1
	MORONE AMERICANA	1	9088	7.0	1.9	13.9	10.1
810423	MORONE AMERICANA	31	9088	7.0	68.4	16.0	9.7
	PERCA FLAVESCENS	1	9088	7.0	2.3	16.0	9.7
810430	MORONE AMERICANA	63	9088	7.0	141.1	18.0	9.4
	DOROSOMA CEPEDIANUM	11	9088	7.0	24.3	18.0	9.4
810507	MORONE AMERICANA	118	10386	8.0	262.3	18.4	8.8
	DOROSOMA CEPEDIANUM	72	10386	8.0	161.0	18.4	8.8
	POMOXIS NIGROMACULATUS	1	10386	8.0	2.1	18.4	8.8
810514	DOROSOMA CEPEDIANUM	165	5193	4.0	419.3	19.7	8.9
	MORONE AMERICANA	65	5193	4.0	169.1	19.7	8.9
	POMOXIS NIGROMACULATUS	1	5193	4.0	2.8	19.7	8.9
810521	DOROSOMA CEPEDIANUM	331	9088	7.0	714.0	18.9	8.8
	MORONE AMERICANA	77	9088	7.0	164.1	18.9	8.8
	POMOXIS NIGROMACULATUS	3	9088	7.0	7.1	18.9	8.8
810528	DOROSOMA CEPEDIANUM	288	10386	8.0	588.3	22.7	8.4
	MORONE AMERICANA	25	10386	8.0	51.9	22.7	8.4
	POMOXIS NIGROMACULATUS	1	10386	8.0	2.3	22.7	8.4
810604	DOROSOMA CEPEDIANUM	85	9088	7.0	218.3	23.6	8.4
	MORONE AMERICANA	6	9088	7.0	16.3	23.6	8.4
	LEPOMIS SP.	1	9088	7.0	2.7	23.6	8.4
810611	DOROSOMA CEPEDIANUM	119	8763	6.8	296.7	26.2	7.9
	POMOXIS NIGROMACULATUS	6	8828	6.8	15.8	26.2	7.9
	MORONE AMERICANA	5	8828	6.8	14.2	26.2	7.9
	LEPOMIS SP.	3	8828	6.8	7.8	26.2	7.9
810618	LEPOMIS SP.	55	10386	8.0	148.3	28.7	7.5
	DOROSOMA CEPEDIANUM	41	10386	8.0	89.0	28.7	7.5
	POMOXIS NIGROMACULATUS	4	10386	8.0	10.4	28.7	7.5
810625	LEPOMIS SP.	5	9088	7.0	28.0	28.6	7.7
	DOROSOMA CEPEDIANUM	3	9088	7.0	9.2	28.6	7.7
810702	LEPOMIS SP.	11	9088	7.0	20.4	26.8	7.1
	DOROSOMA CEPEDIANUM	4	9088	7.0	6.7	26.8	7.1
810709	LEPOMIS SP.	8	9088	7.0	17.9	28.3	7.6
	DOROSOMA CEPEDIANUM	3	9088	7.0	6.0	28.3	7.6

TABLE 6.2.2 LARVAE ENTRAINED DURING SAMPLE DATES AT NORTH ANNA POWER STATION DURING 1978-1983. DISSOLVED OXYGEN AND TEMPERATURE VALUES ARE AVERAGES OF SURFACE SAMPLES.

DATE	SPECIES	CATCH	VOLUME (X1000)	AVERAGE PUMPS	AVERAGE FISH PER CUBIC METER	TEMPERATURE	DISSOLVED OXYGEN
810716	LEPOMIS SP.	24	9088	7.0	50.7	28.1	7.4
	DOROSOMA CEPEDIANUM	4	9088	7.0	7.6	28.1	7.4
810723	LEPOMIS SP.	8	9088	7.0	21.2	28.8	7.9
810730	LEPOMIS SP.	2	9088	7.0	4.6	28.4	7.3
820304		.	7790	6.0	.	8.0	11.3
820310		.	3895	3.0	.	8.0	11.7
820311		.	3895	3.0	.	8.0	11.7
820317		.	5193	4.0	.	10.5	10.4
820318		.	5193	4.0	.	10.9	11.7
820324		.	5193	4.0	.	11.0	11.0
820325	PERCA FLAVESCENS	5	5193	4.0	14.8	12.0	11.1
820401	PERCA FLAVESCENS	1	5193	4.0	2.8	10.3	10.5
820407	PERCA FLAVESCENS	21	5193	4.0	60.6	10.1	10.6
820415	PERCA FLAVESCENS	5	3895	3.0	15.9	12.8	10.4
820422	MORONE AMERICANA	22	3895	3.0	72.8	14.0	10.3
	PERCA FLAVESCENS	3	3895	3.0	10.0	14.0	10.3
	DOROSOMA CEPEDIANUM	1	3895	3.0	3.3	14.0	10.3
820429	MORONE AMERICANA	22	3895	3.0	75.4	16.2	9.4
	PERCA FLAVESCENS	2	3895	3.0	6.2	16.2	9.4
	DOROSOMA CEPEDIANUM	1	3895	3.0	3.2	16.2	9.4
820506	MORONE AMERICANA	77	3895	3.0	302.3	19.3	9.6
	DOROSOMA CEPEDIANUM	12	3895	3.0	47.9	19.3	9.6
	LEPOMIS SP.	4	3895	3.0	15.1	19.3	9.6
820513	MORONE AMERICANA	126	3895	3.0	398.5	22.0	9.3
	DOROSOMA CEPEDIANUM	31	3895	3.0	97.4	22.0	9.3
	LEPOMIS SP.	8	3895	3.0	26.3	22.0	9.3
	POMOXIS NIGROMACULATUS	1	3895	3.0	3.4	22.0	9.3
820520	DOROSOMA CEPEDIANUM	46	7790	6.0	120.6	22.9	8.6
	MORONE AMERICANA	34	7790	6.0	93.1	22.9	8.6
	LEPOMIS SP.	3	7790	6.0	7.7	22.9	8.6
	POMOXIS NIGROMACULATUS	1	7790	6.0	3.7	22.9	8.6

TABLE 6.2.2 LARVAE ENTRAINED DURING SAMPLE DATES AT NORTH ANNA POWER STATION DURING 1978-1983. DISSOLVED OXYGEN AND TEMPERATURE VALUES ARE AVERAGES OF SURFACE SAMPLES.

DATE	SPECIES	CATCH	VOLUME (X1000)	AVERAGE PUMPS	AVERAGE FISH PER CUBIC METER	TEMPERATURE	DISSOLVED OXYGEN
820527	DOROSOMA CEPEDIANUM	47	3895	3.0	147.2	22.0	8.7
	LEPOMIS SP.	23	3895	3.0	75.4	22.0	8.7
	POMOXIS NIGROMACULATUS	4	3895	3.0	13.4	22.0	8.7
	MORONE AMERICANA	1	3895	3.0	4.7	22.0	8.7
820603	DOROSOMA CEPEDIANUM	128	3895	3.0	280.9	25.2	8.3
	MORONE AMERICANA	9	3895	3.0	17.9	25.2	8.3
	LEPOMIS SP.	7	3895	3.0	24.3	25.2	8.3
820610	DOROSOMA CEPEDIANUM	146	3895	3.0	416.5	23.4	8.5
	LEPOMIS SP.	4	3895	3.0	13.1	23.4	8.5
	MORONE AMERICANA	1	3895	3.0	2.6	23.4	8.5
820617	DOROSOMA CEPEDIANUM	19	3895	3.0	51.1	23.8	8.6
820624	DOROSOMA CEPEDIANUM	22	5193	4.0	60.0	25.7	8.7
	LEPOMIS SP.	22	5193	4.0	76.2	25.7	8.7
820701	DOROSOMA CEPEDIANUM	14	5193	4.0	45.5	27.0	8.4
	LEPOMIS SP.	3	5193	4.0	11.1	27.0	8.4
	MORONE AMERICANA	1	5193	4.0	2.6	27.0	8.4
820708	LEPOMIS SP.	9	5193	4.0	30.2	27.4	7.9
	DOROSOMA CEPEDIANUM	1	5193	4.0	2.8	27.4	7.9
820715	LEPOMIS SP.	29	3895	3.0	119.6	28.7	8.1
	DOROSOMA CEPEDIANUM	2	3895	3.0	6.2	28.7	8.1
820722	DOROSOMA CEPEDIANUM	1	3895	3.0	4.5	29.0	8.3
820729	LEPOMIS SP.	2	3895	3.0	6.8	29.3	8.0
830303	NO LARVAE	.	7790	6.0	.	7.8	11.8
830310	NO LARVAE	.	7790	6.0	.	9.8	11.7
830317	NO LARVAE	.	7790	6.0	.	10.3	11.0
830323	NO LARVAE	.	7790	6.0	.	10.2	10.8
830330	PERCA FLAVESCENS	4	7790	6.0	9.3	10.8	10.8
830407	PERCA FLAVESCENS	8	3895	3.0	21.4	12.7	10.6
830414	PERCA FLAVESCENS	10	3895	3.0	26.6	12.4	10.4
	MORONE AMERICANA	9	3895	3.0	22.8	12.4	10.4

TABLE 6.2.2 LARVAE ENTRAINED DURING SAMPLE DATES AT NORTH ANNA POWER STATION DURING 1978-1983. DISSOLVED OXYGEN AND TEMPERATURE VALUES ARE AVERAGES OF SURFACE SAMPLES.

DATE	SPECIES	CATCH	VOLUME (X1000)	AVERAGE PUMPS	AVERAGE FISH PER CUBIC METER	TEMPERATURE	DISSOLVED OXYGEN
830421	MORONE AMERICANA	16	3895	3.0	40.4	12.0	10.2
	PERCA FLAVESCENS	2	3895	3.0	5.3	12.0	10.2
830428	MORONE AMERICANA	39	3895	3.0	105.1	14.3	10.8
830505	MORONE AMERICANA	20	3895	3.0	53.0	18.0	9.9
	DOROSOMA CEPEDIANUM	6	3895	3.0	15.5	18.0	9.9
830512	MORONE AMERICANA	146	5193	4.0	423.8	19.8	9.7
	DOROSOMA CEPEDIANUM	131	5193	4.0	397.5	19.8	9.7
	POMOXIS NIGROMACULATUS	28	5193	4.0	81.4	19.8	9.7
	LEPOMIS SP.	3	5193	4.0	9.2	19.8	9.7
830519	DOROSOMA CEPEDIANUM	55	3895	3.0	144.4	18.7	9.1
	MORONE AMERICANA	39	3895	3.0	102.5	18.7	9.1
830526	DOROSOMA CEPEDIANUM	201	9088	7.0	428.1	21.7	8.9
	MORONE AMERICANA	37	9088	7.0	70.8	21.7	8.9
830602	DOROSOMA CEPEDIANUM	89	9088	7.0	181.3	21.9	8.9
	MORONE AMERICANA	8	9088	7.0	15.3	21.9	8.9
	LEPOMIS SP.	1	9088	7.0	2.2	21.9	8.9
830609	DOROSOMA CEPEDIANUM	94	9088	7.0	180.9	24.0	8.4
	MORONE AMERICANA	16	9088	7.0	30.8	24.0	8.4
	LEPOMIS SP.	1	9088	7.0	2.2	24.0	8.4
830616	DOROSOMA CEPEDIANUM	87	9088	7.0	169.5	27.7	7.7
	MORONE AMERICANA	11	9088	7.0	25.4	27.7	7.7
	LEPOMIS SP.	1	9088	7.0	1.4	27.7	7.7
830623	DOROSOMA CEPEDIANUM	42	10386	8.0	78.1	27.3	6.9
	MORONE AMERICANA	11	10386	8.0	29.4	27.3	6.9
	LEPOMIS SP.	3	10386	8.0	7.5	27.3	6.9
	ICTALURUS PUNCTATUS	1	10386	8.0	1.8	27.3	6.9
	POMOXIS NIGROMACULATUS	1	10386	8.0	3.0	27.3	6.9
830630	DOROSOMA CEPEDIANUM	20	10386	8.0	39.1	26.8	7.2
	MORONE AMERICANA	5	10386	8.0	10.5	26.8	7.2
830707	LEPOMIS SP.	10	10386	8.0	21.5	27.4	7.6
	DOROSOMA CEPEDIANUM	4	10386	8.0	6.8	27.4	7.6
	MORONE AMERICANA	1	10386	8.0	2.0	27.4	7.6
830714	LEPOMIS SP.	8	10386	8.0	14.9	29.4	7.9
	DOROSOMA CEPEDIANUM	4	10386	8.0	5.2	29.4	7.9
	MORONE AMERICANA	2	10386	8.0	3.8	29.4	7.9

TABLE 6.2.2 LARVAE ENTRAINED DURING SAMPLE DATES AT NORTH ANNA POWER STATION DURING 1978-1983. DISSOLVED OXYGEN AND TEMPERATURE VALUES ARE AVERAGES OF SURFACE SAMPLES.

DATE	SPECIES	CATCH	VOLUME (X1000)	AVERAGE PUMPS	AVERAGE FISH PER CUBIC METER	TEMPERATURE	DISSOLVED OXYGEN
830721	LEPOMIS SP.	1	9088	7.0	2.1	31.0	7.5
	MORONE AMERICANA	1	9088	7.0	3.7	31.0	7.5
830728	NO LARVAE	.	10062	7.8	.	28.7	6.6

TABLE 6.2.3. TOTAL LARVAE COLLECTED BY YEAR AND SAMPLE TIME AT NORTH ANNA POWER STATION , 1978-1983.

YEAR	SPECIES	HOURS: 0600	%	1200	%	1800	%	2400	%	TOTAL
78	DOROSOMA CEPEDIANUM	90	17.5	63	12.3	95	18.5	266	51.8	514
	LEPOMIS SPP.	80	15.1	199	37.5	144	27.1	108	20.3	531
	MICROPTERUS SALMOIDES			1	100.0					1
	MORONE AMERICANA							3	100.0	3
	PERCA FLAVESCENS	14	10.8	35	26.9	46	35.4	35	26.9	130
	POMOXIS NIGROMACULATUS	4	33.3	6	50.0	1	8.3	1	8.3	12
	TOTAL	188	15.8	304	25.5	286	24.0	413	34.7	1191
79	DOROSOMA CEPEDIANUM	153	11.0	167	12.0	337	24.1	740	53.0	1397
	LEPOMIS SPP.	16	14.3	26	23.2	37	33.0	33	29.5	112
	MORONE AMERICANA	3	5.4	13	23.2	11	19.6	29	51.8	56
	PERCA FLAVESCENS	3	16.7	13	72.2			2	11.1	18
	POMOXIS NIGROMACULATUS	1	16.7			3	50.0	2	33.3	6
	TOTAL	176	11.1	219	13.8	388	24.4	806	50.7	1589
80	DOROSOMA CEPEDIANUM	215	22.8	106	11.3	158	16.8	462	49.1	941
	LEPOMIS SPP.	18	11.2	55	34.2	64	39.8	24	14.9	161
	MORONE AMERICANA	13	14.3	8	8.8	16	17.6	54	59.3	91
	PERCA FLAVESCENS	17	23.6	19	26.4	3	4.2	33	45.8	72
	POMOXIS NIGROMACULATUS	4	30.8	2	15.4	6	46.2	1	7.7	13
	TOTAL	267	20.9	190	14.9	247	19.3	574	44.9	1278
81	DOROSOMA CEPEDIANUM	173	15.4	143	12.7	277	24.6	533	47.3	1126
	LEPOMIS SPP.	43	36.8	38	32.5	26	22.2	10	8.5	117
	MORONE AMERICANA	53	13.6	57	14.6	114	29.2	167	42.7	391
	PERCA FLAVESCENS	15	14.6	12	11.7	41	39.8	35	34.0	103
	POMOXIS NIGROMACULATUS	2	12.5	5	31.3	5	31.3	4	25.0	16
	TOTAL	286	16.3	255	14.5	463	26.4	749	42.7	1753
82	DOROSOMA CEPEDIANUM	88	18.7	66	14.0	28	5.9	289	61.4	471
	LEPOMIS SPP.	31	27.2	52	45.6	10	8.8	21	18.4	114
	MORONE AMERICANA	29	9.9	58	19.8	43	14.7	163	55.6	293
	PERCA FLAVESCENS	3	8.1	10	27.0	7	18.9	17	45.9	37
	POMOXIS NIGROMACULATUS	2	33.3	2	33.3	1	16.7	1	16.7	6
	TOTAL	153	16.6	188	20.4	89	9.7	491	53.3	921
83	DOROSOMA CEPEDIANUM	140	19.1	215	29.3	137	18.7	241	32.9	733
	ICTALURUS PUNCTATUS							1	100.0	1
	LEPOMIS SPP.	3	10.7	13	46.4	8	28.6	4	14.3	28
	MORONE AMERICANA	62	17.2	133	36.8	57	15.8	109	30.2	361
	PERCA FLAVESCENS	10	41.7	3	12.5	5	20.8	6	25.0	24
	POMOXIS NIGROMACULATUS	1	3.4	18	62.1	3	10.3	7	24.1	29
	TOTAL	216	18.4	382	32.5	210	17.9	368	31.3	1176
	GRAND TOTAL	1286	16.3	1538	19.4	1683	21.3	3401	43.0	7908

TABLE 6.2.4. TOTAL LARVAE COLLECTED BY SPECIES AND SAMPLE TIME AT NORTH ANNA POWER STATION , 1978-1983.

SPECIES	YEAR	0600	%	1200	%	1800	%	2400	%	TOTAL
DOROSOMA CEPEDIANUM	78	90	17.5	63	12.3	95	18.5	266	51.8	514
	79	153	11.0	167	12.0	337	24.1	740	53.0	1397
	80	215	22.8	106	11.3	158	16.8	462	49.1	941
	81	173	15.4	143	12.7	277	24.6	533	47.3	1126
	82	88	18.7	66	14.0	28	5.9	289	61.4	471
	83	140	19.1	215	29.3	137	18.7	241	32.9	733
	TOTAL	859	16.6	760	14.7	1032	19.9	2531	48.8	5182
ICTALURUS PUNCTATUS	83							1	100.0	1
	TOTAL							1	100.0	1
LEPOMIS SPP.	78	80	15.1	199	37.5	144	27.1	108	20.3	531
	79	16	14.3	26	23.2	37	33.0	33	29.5	112
	80	18	11.2	55	34.2	64	39.8	24	14.9	161
	81	43	36.8	38	32.5	26	22.2	10	8.5	117
	82	31	27.2	52	45.6	10	8.8	21	18.4	114
	83	3	10.7	13	46.4	8	28.6	4	14.3	28
	TOTAL	191	18.0	383	36.0	289	27.2	200	18.8	1063
MICROPTERUS SALMOIDES	78			1	100.0					1
	TOTAL			1	100.0					1
MORONE AMERICANA	78							3	100.0	3
	79	3	5.4	13	23.2	11	19.6	29	51.8	56
	80	13	14.3	8	8.8	16	17.6	54	59.3	91
	81	53	13.6	57	14.6	114	29.2	167	42.7	391
	82	29	9.9	58	19.8	43	14.7	163	55.6	293
	83	62	17.2	133	36.8	57	15.8	109	30.2	361
	TOTAL	160	13.4	269	22.5	241	20.2	525	43.9	1195
PERCA FLAVESCENS	78	14	10.8	35	26.9	46	35.4	35	26.9	130
	79	3	16.7	13	72.2			2	11.1	18
	80	17	23.6	19	26.4	3	4.2	33	45.8	72
	81	15	14.6	12	11.7	41	39.8	35	34.0	103
	82	3	8.1	10	27.0	7	18.9	17	45.9	37
	83	10	41.7	3	12.5	5	20.8	6	25.0	24
	TOTAL	62	16.1	92	24.0	102	26.6	128	33.3	384
POMOXIS NIGROMACULATUS	78	4	33.3	6	50.0	1	8.3	1	8.3	12
	79	1	16.7			3	50.0	2	33.3	6
	80	4	30.8	2	15.4	6	46.2	1	7.7	13
	81	2	12.5	5	31.3	5	31.3	4	25.0	16
	82	2	33.3	2	33.3	1	16.7	1	16.7	6
	83	1	3.4	18	62.1	3	10.3	7	24.1	29
	TOTAL	14	17.1	33	40.2	19	23.2	16	19.5	82
GRAND TOTAL		1286	16.3	1538	19.4	1683	21.3	3401	43.0	7908

TABLE 6.2.5. TOTAL LARVAE COLLECTED BY SPECIES AND SAMPLE DEPTH AT NORTH ANNA POWER STATION, 1978-1983.

YEAR	SPECIES	SURFACE	PERCENT	MIDDLE	PERCENT	BOTTOM	PERCENT	TOTAL
78	DOROSOMA CEPEDIANUM	100	19	296	58	118	23	514
	LEPOMIS SPP.	403	76	72	14	56	11	531
	MICROPTERUS SALMOIDES	1	100	0	0	0	0	1
	MORONE AMERICANA	0	0	3	100	0	0	3
	PERCA FLAVESCENS	86	66	20	15	24	18	130
	POMOXIS NIGROMACULATUS	7	58	1	8	4	33	12
	TOTAL	597	50	392	33	202	17	1191
79	DOROSOMA CEPEDIANUM	408	29	478	34	511	37	1397
	LEPOMIS SPP.	84	75	18	16	10	9	112
	MORONE AMERICANA	16	29	26	46	14	25	56
	PERCA FLAVESCENS	15	83	2	11	1	6	18
	POMOXIS NIGROMACULATUS	5	83	1	17	0	0	6
	TOTAL	528	33	525	33	536	34	1589
80	DOROSOMA CEPEDIANUM	111	12	463	49	367	39	941
	LEPOMIS SPP.	133	83	13	8	15	9	161
	MORONE AMERICANA	17	19	33	36	41	45	91
	PERCA FLAVESCENS	40	56	9	13	23	32	72
	POMOXIS NIGROMACULATUS	10	77	2	15	1	8	13
	TOTAL	311	24	520	41	447	35	1278
81	DOROSOMA CEPEDIANUM	219	19	473	42	434	39	1126
	LEPOMIS SPP.	102	87	6	5	9	8	117
	MORONE AMERICANA	125	32	129	33	137	35	391
	PERCA FLAVESCENS	74	72	18	17	11	11	103
	POMOXIS NIGROMACULATUS	14	88	1	6	1	6	16
	TOTAL	534	30	627	36	592	34	1753
82	DOROSOMA CEPEDIANUM	63	13	186	39	222	47	471
	LEPOMIS SPP.	92	81	12	11	10	9	114
	MORONE AMERICANA	123	42	87	30	83	28	293
	PERCA FLAVESCENS	17	46	8	22	12	32	37
	POMOXIS NIGROMACULATUS	5	83	1	17	0	0	6
	TOTAL	300	33	294	32	327	36	921
83	DOROSOMA CEPEDIANUM	146	20	276	38	311	42	733
	ICTALURUS PUNCTATUS	0	0	0	0	1	100	1
	LEPOMIS SPP.	16	57	8	29	4	14	28
	MORONE AMERICANA	154	43	105	29	102	28	361
	PERCA FLAVESCENS	14	58	3	13	7	29	24
	POMOXIS NIGROMACULATUS	19	66	10	34	0	0	29
	TOTAL	349	30	402	34	425	36	1176
	GRAND TOTAL	2619	33	2760	35	2529	32	7908

TABLE 6.2.6. TOTAL LARVAE COLLECTED BY YEAR AND SAMPLE DEPTH AT NORTH ANNA POWER STATION, 1978-1983.

SPECIES	YEAR	SURFACE	PERCENT	MIDDLE	PERCENT	BOTTOM	PERCENT	TOTAL
DOROSOMA CEPEDIANUM	78	100	19	296	58	118	23	514
	79	408	29	478	34	511	37	1397
	80	111	12	463	49	367	39	941
	81	219	19	473	42	434	39	1126
	82	63	13	186	39	222	47	471
	83	146	20	276	38	311	42	733
TOTAL	TOTAL	1047	20	2172	42	1963	38	5182
ICTALURUS PUNCTATUS	83	0	0	0	0	1	100	1
TOTAL	TOTAL	0	0	0	0	1	100	1
LEPOMIS SPP.	78	403	76	72	14	56	11	531
	79	84	75	18	16	10	9	112
	80	133	83	13	8	15	9	161
	81	102	87	6	5	9	8	117
	82	92	81	12	11	10	9	114
	83	16	57	8	29	4	14	28
TOTAL	TOTAL	830	78	129	12	104	10	1063
MICROPTERUS SALMOIDES	78	1	100	0	0	0	0	1
TOTAL	TOTAL	1	100	0	0	0	0	1
MORONE AMERICANA	78	0	0	3	100	0	0	3
	79	16	29	26	46	14	25	56
	80	17	19	33	36	41	45	91
	81	125	32	129	33	137	35	391
	82	123	42	87	30	83	28	293
	83	154	43	105	29	102	28	361
TOTAL	TOTAL	435	36	383	32	377	32	1195
PERCA FLAVESCENS	78	86	66	20	15	24	18	130
	79	15	83	2	11	1	6	18
	80	40	56	9	13	23	32	72
	81	74	72	18	17	11	11	103
	82	17	46	8	22	12	32	37
	83	14	58	3	13	7	29	24
TOTAL	TOTAL	246	64	60	16	78	20	384
POMOXIS NIGROMACULATUS	78	7	58	1	8	4	33	12
	79	5	83	1	17	0	0	6
	80	10	77	2	15	1	8	13
	81	14	88	1	6	1	6	16
	82	5	83	1	17	0	0	6
	83	19	66	10	34	0	0	29
TOTAL	TOTAL	60	73	16	20	6	7	82
GRAND TOTAL		2619	33	2760	35	2529	32	7908

TABLE 6.2.7. ESTIMATES AND ASSOCIATED 95% CONFIDENCE LIMITS FOR LARVAE ENTRAINED 1978-1983 AT NORTH ANNA POWER STATION.

YEAR	SPECIES	LOWER CONFIDENCE LIMIT (X1,000,000)	ESTIMATE (X1,000,000)	UPPER CONFIDENCE LIMIT (X1,000,000)
78				
	DOROSOMA CEPEDIANUM	53.6	60.4	67.2
	LEPOMIS SPP.	56.9	64.2	71.5
	MICROPTERUS SALMOIDES	0.1	0.1	0.2
	MORONE AMERICANA	0.2	0.3	0.5
	PERCA FLAVESCENS	11.5	12.7	14.0
	POMOXIS NIGROMACULATUS	1.4	1.8	2.1
	TOTAL	129.3	139.6	149.8
79				
	DOROSOMA CEPEDIANUM	117.2	128.1	138.9
	LEPOMIS SPP.	9.7	10.9	12.1
	MORONE AMERICANA	5.5	6.3	7.2
	PERCA FLAVESCENS	1.4	2.0	2.6
	POMOXIS NIGROMACULATUS	0.6	0.7	0.9
	TOTAL	137.0	148.1	159.3
80	DOROSOMA CEPEDIANUM	94.6	103.3	112.1
	LEPOMIS SPP.	20.2	22.3	24.3
	MORONE AMERICANA	10.7	11.5	12.4
	PERCA FLAVESCENS	5.3	6.0	6.6
	POMOXIS NIGROMACULATUS	1.2	1.5	1.7
	TOTAL	135.2	144.6	153.9
81	DOROSOMA CEPEDIANUM	143.3	157.1	170.9
	LEPOMIS SPP.	18.4	20.5	22.6
	MORONE AMERICANA	50.8	54.8	58.8
	PERCA FLAVESCENS	13.0	14.4	15.8
	POMOXIS NIGROMACULATUS	2.2	2.6	2.9
	TOTAL	233.1	249.4	265.8
82				
	DOROSOMA CEPEDIANUM	35.4	39.4	43.3
	LEPOMIS SPP.	10.5	12.4	14.2
	MORONE AMERICANA	26.1	29.0	31.9
	PERCA FLAVESCENS	3.4	3.7	4.1
	POMOXIS NIGROMACULATUS	0.5	0.7	0.8
	TOTAL	79.4	85.1	90.7
83	DOROSOMA CEPEDIANUM	82.9	89.3	95.6
	ICTALURUS PUNCTATUS	0.1	0.1	0.2
	LEPOMIS SPP.	3.3	4.0	4.7
	MORONE AMERICANA	33.1	36.8	40.6
	PERCA FLAVESCENS	1.6	2.0	2.3
	POMOXIS NIGROMACULATUS	2.6	3.2	3.8
	TOTAL	127.1	135.4	143.7

FIGURE 6.2.1. TOTAL ENTRAINMENT CATCH PER PUMP OF SELECTED ABUNDANT SPECIES AT NORTH ANNA POWER STATION, 1978-1983.

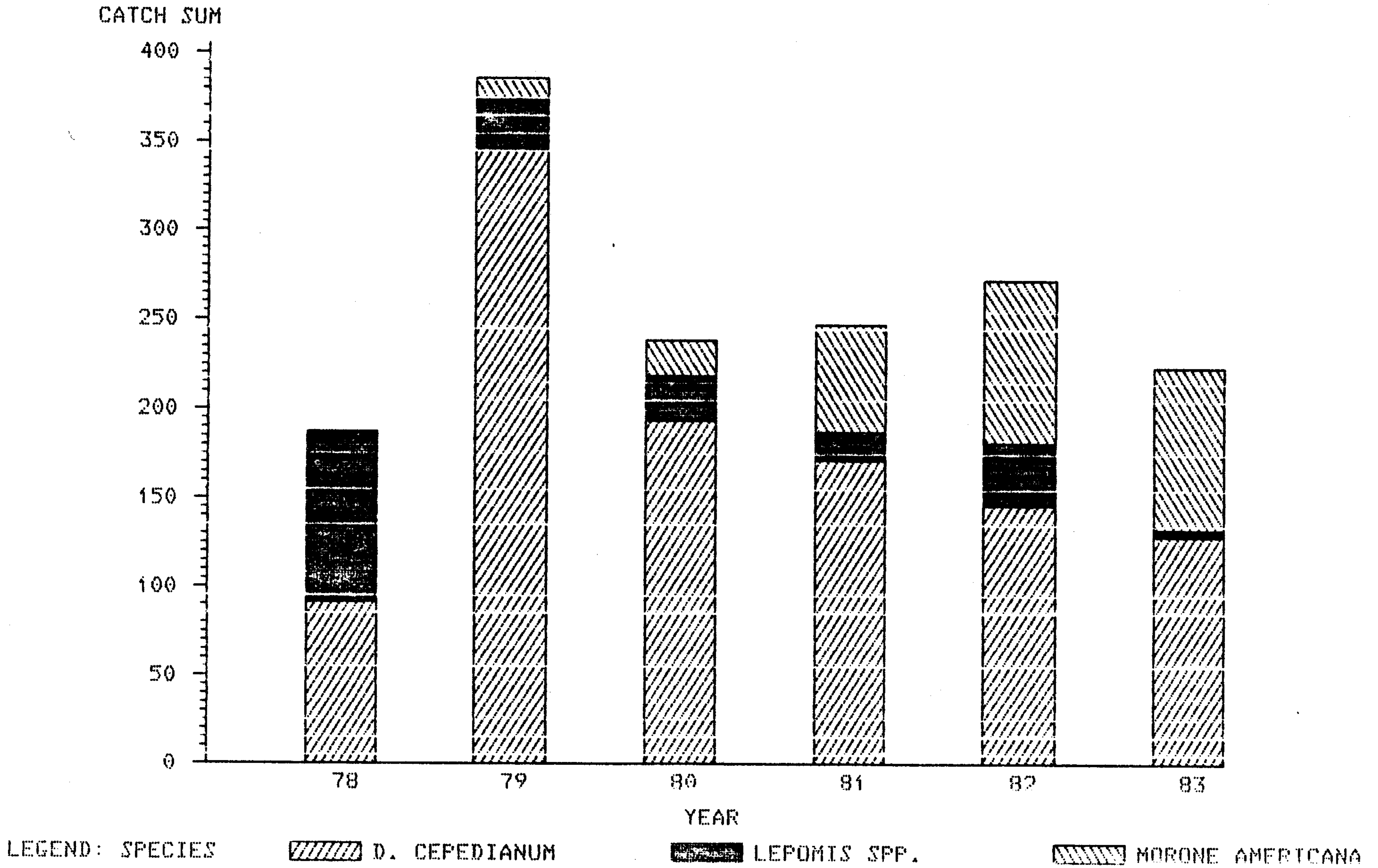
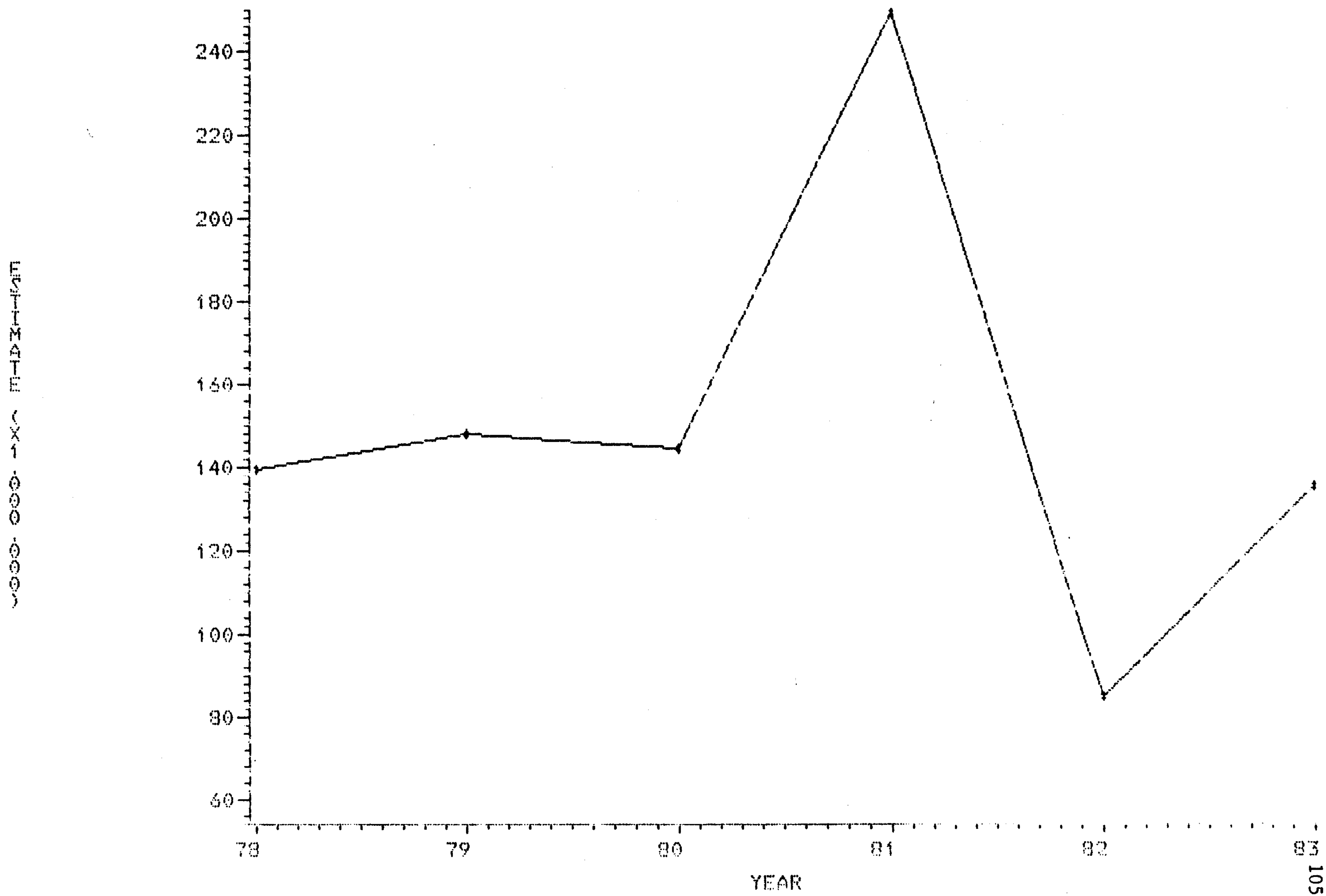


FIGURE 6.2.2. ESTIMATED TOTAL NUMBER OF FISH LARVAE ENTRAINED PER YEAR AT NORTH ANNA POWER STATION, 1978-1983.



7.0 IMPACT ASSESSMENT

7.1 Impingement

The impact of impingement during this 5-year 9-month study period on the Lake Anna fishery will be discussed from three perspectives: (1) comparison of impingement losses by major species with total lake standing crop derived from rotenone estimates; (2) comparison of losses due to impingement by major species with the average fecundity of these species and; (3) comparison of impingement losses with creel losses, when available.

Impingement rates are related to fecundity, the general term used to describe the number of eggs produced by fish (Lagler, et al. 1962). The number of eggs produced by an individual female varies according to a great many factors including age, size, environmental condition, and species. Some eggs are buoyant (pelagic) and have specific gravity about the same as fresh water; however, most lake fish produce eggs that are heavier than fresh water, which causes them to sink (demersal) and have an adhesive coating that holds them to a substrate and prevents them from being swept away by current (Reutter and Herdendorf 1979).

The percentage of eggs produced by a single female fish that actually grow to adult size is very small, especially for broadcast spawners. This percent survival is affected by many factors including physical parameters, predation and the principle of compensation. The fecundity of selected species, as discussed below, is described in terms of potential replacement and is presented only to show the disparity of the number of fishes impinged versus the fecundity of each species.

Gizzard Shad

The average annual standing crop of gizzard shad (1979-1983) was 121 kg/ha (Vepco 1983 and 1984). This value may well be an underestimate as gizzard shad is a schooling species and the probability of capturing a school in a given cove is low. Porak and Tranquilli (1981) found the average standing crop of gizzard shad in Lake Sangchris, Illinois to be 275.3 kg/ha, but that is a much smaller lake than Lake Anna (less than 1/4 of the surface area). The average annual weight of gizzard shad impinged in Lake Anna during the 5-plus-year study period was 2,200 kg (Table 6.1.3). Thus 0.32% of the Lake area (18 of 5,600 ha) would be required annually to produce the weight of impinged gizzard shad. Stated another way, an average 0.32% of the total gizzard shad standing crop (by weight) was impinged annually. The number of gizzard shad per hectare, from rotenone data, is only readily available for the years 1981-1983. Using these 3 years of data, averaged, the annual standing crop number was 1.7×10^3/ha and the average annual number impinged during this 3-year period was 3.4×10^4 (Table 6.1.3). Thus 0.38% of the Lake area (21 of 5,600 ha) would be required annually to produce the number of impinged gizzard shad. This value is much smaller than found in the Lake Sangchris study, 1.82% (Porak and Tranquilli 1981).

Gizzard shad have a high reproductive potential and a rapid growth rate. They can reproduce at 2 years of age and the number of eggs contained in a female can range from 2.2×10^4 to 5.4×10^5 (Carlander 1969) dependent on their age and size with an average of 3.8×10^5 for age class II (Jones 1978). The average yearly estimate of impinged gizzard shad at the North Anna Power Station was 1.2×10^5 for the 5-plus-year study (Table 6.1.3), considerably less than the maximum fecundity potential of one average size 2-year-old female gizzard shad.

Black Crappie

Preoperational cove rotenone studies show a 52% drop in black crappie standing crop between 1976 and 1977 at three coves sampled on Lake Anna (Vepco 1984). The Pamunkey Arm cove was not sampled during 1976. After impingement startup in April 1978, August cove rotenone studies showed an additional 86% (1977 versus 1978) drop in black crappie standing crop at the three coves sampled during 1976. The Pamunkey Creek cove in the upper lake, approximately seven miles above the intake area, showed a 70% drop in black crappie standing crop between 1977 and 1978 (Vepco 1978). It is unlikely this station could have been affected by only four months of station operation. It would appear, therefore, that the decline of the black crappie standing crop is unrelated to station operation.

Results of cove rotenone studies at Lake Anna have indicated a steady decline of black crappie since 1978 (Vepco 1983 and 1984). The average annual standing crop of black crappie for the five years is 6.64 kg/ha (Vepco 1983 and 1984). The average annual weight of black crappie impinged during the 5-plus-year study was 1,397.3 kg. Thus 3.8% of the lake area (210 of 5,600 ha) would be required annually to produce the weight of impinged black crappie, or an average 3.8% of the total black crappie standing crop (by weight) was impinged annually. The number of black crappie per hectare, from rotenone data, is readily available only for the years 1981-1983. The 3-year average annual standing crop (number) was 130/ha (Vepco 1983 and 1984) and the average annual number impinged was 2.2×10^4. Thus 3.1% of the lake area (171 of 5,600 ha) would be required annually to produce the number of black crappie impinged in the lake.

The average fecundity of black crappie has been estimated at 3.8×10^4 with a maximum of 1.6×10^5 eggs (Hardy, 1978). Since the estimated average annual number of black crappie impinged was 2.8×10^4 for the five-year study period, one average size adult female could theoretically produce more progeny in one year than were impinged in a year. Black crappie fecundity was not affected by temperature increases caused by heated discharge from a nuclear power station in Keowee Reservoir in South Carolina (Barwick 1981).

The Virginia Commission of Game and Inland Fisheries conducted a creel survey on Lake Anna from 1976 through 1979 (Sledd and Shuber 1981). The number of black crappie estimated creeled in 1979 was considerably less than each of the preceeding 3 years (5.7×10^4 vs. an avg. of 1.0×10^5). During 1979 an estimated 3.9×10^4 black crappie were impinged (Table 6.1.3); this value is 32% (56,634) less than were estimated to have been creeled that year. The combined creel and impingement estimate for 1979 (9.5×10^4) was only 87% (1.1×10^5) of the total creeled in 1978. Since such a small number of black crappie were impinged in 1979, the start-up of impingement could not have been responsible for the abrupt decline of black crappie which began that year. Rather, the cause is probably due to natural fluctuations in numbers which according to Swingle and Swingle (1968) occur frequently in black crappie populations.

The next time a creel survey was conducted at Lake Anna was in 1984. As there is no impingement data available for that year, the 1984 creel data were compared to 1983 impingement data. During 9 months of creel surveys at Lake Anna in 1984 (March through November) an estimated 1.6×10^4 black crappie weighing 1,225.5 kg were creeled (Vepco unpublished data). During 1983 (January through December) an estimated 1.1×10^4 black crappie weighing 556.8

kg were impinged (Table 6.1.3). Forty-five percent more fish were creeled than impinged if 1983 is considered to be a comparable year to 1984 for black crappie. The weight difference between the creeled fish (average 75.3g) and impinged fish (average 50.5g) would tend to indicate that anglers were keeping only the larger, more mature fish whereas the traveling screens collect a more indescriminate sample with many more smaller fish. However, impingement data indicate that the majority of the black crappie impinged were larger than 150 mmT.L. (Figure 6.1.1). Therefore, this weight difference may indicate that the impinged black crappie were, in many cases, weak and emaciated and probably would have been susceptible to predation in the lake under normal conditions. As the creel survey did not include lengths, this hypothesis cannot be confirmed.

Yellow Perch

As discussed earlier in the "Results" section, cove rotenone data probably underestimate the yellow perch standing crop in Lake Anna. They are, however, the best indicators available for the standing crop of that species. The average annual yellow perch standing crop for the 5-plus-year study period was 6.5 kg/ha (Vepco 1983 and 1984) and the estimated average annual impingement weight was 518.1 kg (Table 6.1.3). Since 1.4% of the lake area (80 of 5,600 ha) would be required annually to produce the weight of impinged yellow perch, then an average 1.4% of the total yellow perch standing crop was impinged annually. The number of yellow perch per hectare, from rotenone data, is readily available only for the years 1981-1983. The 3-year average annual standing crop (numerical) was 230/ha and the average annual number impinged was 7.6×10^3 over this 3-year period. Only 0.6% of the lake area (33 of 5,600 ha) would be required annually to produce the number of impinged yellow perch.

The average fecundity of yellow perch has been estimated at 2.3 x 10^4 ranging up to 1.4 x 10^5 (Hardy 1978). Since the estimated annual average number of yellow perch impinged was 2.9 x 10^4 over the 5-plus-year period, 2 average size or one large adult female could theoretically produce more progeny in one year than were impinged annually.

Bluegill

Cove rotenone studies indicate a fairly steady standing crop of bluegill in Lake Anna during the 5-plus-year impingement study period that ranges from 58.8 kg/ha to 74.2 kg/ha with an annual average of 65.3 kg/ha (Vepco 1973 and 1974). The estimated average annual impingement weight for bluegill during the 5-plus-year study period was 80.0 kg (Table 6.1.3). This means 0.02% of the lake area (1.2 of 5,600 ha) would be required annually to produce the weight of impinged bluegill or an average 0.02% of the total bluegill standing crop was impinged annually. The 3-year (1981-1983) average annual standing crop (numerical) was 7.8 x 10^3/ha and the average annual number impinged during that same period was 8.4 10^3 (Table 6.1.3). Thus 0.02% of the lake area (1.1 of 5,600 ha) would be required annually to produce the number of bluegill impinged annually.

The average fecundity of bluegill has been estimated at 1.8 x 10^4 (Hardy 1978) but can be as high as 6.4 x 10^4. As the estimated average annual number of bluegill impinged was 7.4 x 10^3 during the 5-plus-year study (Table 6.1.3), 1 average size adult female theoretically could produce more progeny in 1-year than were impinged in a year.

During the creel survey years (1976-1979) the estimated average annual bluegill harvest was 1.5 x 10^4 fish (Sledd and Shuber 1981). This average is almost twice as high as the average annual impingement rate (7.5×10^3 fish) from 1979-1983. The estimated total number of bluegill creeled during 1984 was 9.0×10^3 (Vepco unpublished data). This value is almost twice as high as the estimated total number of bluegill impinged during 1983 (5.8×10^3) (Table 6.1.3). The comparison of data from these 2 years probably is valid as the standing crop of bluegill in Lake Anna remained relatively stable during that period (Vepco unpublished data).

White Perch

Cove rotenone data indicate an increasing population of white perch in Lake Anna ranging from 2.73 kg/ha in 1979 to 24.2 kg/ha in 1982 and 21.0 kg/ha in 1983 with an annual average during the 5-plus-year study period of 12.7 kg/ha (Vepco 1983 and 1984). The estimated average annual impingement rate for white perch during that period was 122.2 kg. At this rate, 0.1% of the lake area (5.8 of 5,600 ha) would be required annually to produce the weight of impinged white perch, or an average of 0.1% of the total white perch standing crop was impinged annually. The number of white perch per hectare, readily available only for the years 1981-1983 averaged 520/ha from rotenone data (Vepco 1983 and 1984). The estimated average annual impingement number for these 3 years was 3.9×10^3 (Table 6.1.3). Thus 0.13% of the lake area (7.5 of 5,600 ha) would be required to produce the number of white perch impinged annually.

The average fecundity of white perch has been estimated at 4.0×10^4 with a maximum reported at 3.2×10^5 (Hardy 1978). As the estimated average annual number of white perch impinged was 2.7×10^3 during the 5-plus-year study (max. 5,168) (Table 6.1.3), one average size adult female theoretically could produce more progeny in 1-year than were impinged in a year.

Table 7.1.1 - Impact assessment summary for selected species, comparing average annual impingement rates with average annual standing crop, average fecundity and creel estimates when available, at North Anna Power Station 1978-1983.

Species	Average Annual Impingement Weight (kg) 1978-1983	Average Annual Standing Crop (Weight-kg) 1979-1983	Average Annual Impingement Number 1981-1983	Average Annual Standing Crop (Number) 1981-1983	Average Annual Impingement Number 1979-1983	Fecundity of one Average Size Female Fish	Estimated Number Impinged 1983	Estimated Creel Harvest 1984
	0.3%		0.4%					
Gizzard Shad	2,200	677,600	34,417	9,408,000	116,769	378,990	-----	-----
	3.8%		3.1%					
Black Crappie	1,397	37,184	22,256	728,000	28,437	37,796	11,018	15,992
	1.4%		0.6%					
Yellow Perch	518	36,400	7,582	1,288,000	28,634	23,000	-----	-----
	0.02%		0.02%					
Bluegill	80	365,680	8,362	43,456,000	7,438	18,300	5,754	9,056
	5.8%		0.13%					
White perch	122	71,120	3,898	2,912,000	2,719	40,000	-----	-----
Striped bass	Total number impinged - 10,024 total number stocked - 1,508,098. 0.7%							

Table 7.1.2 Lake Anna Fingerling Stocking History 1972-1983

	Largemouth Bass	Channel Cat	Bluegill	Redear	Striped Bass	Walleye	Florida Largemouth	Blueback Herring	Threadfin Shad
1972	357,820	394,458	3,493,477	[1]795,401					
1973					95,000				
1974				201,136					
1975					96,997	58,220			
1976		194,550			293,620		18,650		
1977					[2]164,395		43,639		
1978					208,568				
1979				389,724	367,828				
1980				104,826	213,131			9,000	
1981					238,171	[3]183,663		2,600	
1982					224,787	59,667			
1983					255,613	197,250			5,000

1. Redear shipments contained unestimated percentage of Bluegill
2. Excludes an estimated 9,556 lost on June 29, 1977 shipment
3. 10,000 fry in poor shape also stocked in 1981

7.2 Entrainment

Regardless of the source of a disturbance on fish populations, there exists some natural compensatory capacity within that population. Compensation is the capacity of a population to offset, to some extent, reductions in numbers caused by some disturbance, e.g. commercial fishes and sport fisheries. Compensation has been demonstrated in many fish populations and is the primary basis for sustained commercial fishery operations (McFadden 1977). Ricker (1954) stated that the removal of young fish (eggs, larvae and juveniles) is at least partly balanced by the increased survival of the remaining fish. It is possible that fish populations could withstand exploitation by power plants at levels described in commercial and sport fisheries. The natural compensation capacity of fish populations in Lake Anna should reduce the impact of entrainment by North Anna Power Station.

It has been shown that the mortality rate of larval populations is a major factor in determining fisheries stock stability (Polgar 1977). The effects of entrainment on stock stability can be assessed by determining the number of adults represented by the entrained larvae (Long Island Lighting Co. 1977). Several models were considered for the Lake Anna entrainment program (Horst 1975; Hackney and Webb 1977; and Goodyear 1978). Goodyear's (1978) equivalent adult model was chosen because it eliminates sources of error found in the others that could underestimate impact. The model is based on work that shows larval mortality as being a function of length class (Swedberg and Walburg 1970). Goodyear shows that data on abundance of larvae, grouped by body length can be used to estimate a probability of survival from one length class to the next during the period that larvae are vulnerable to entrainment. The number of adults that would have resulted from the entrained larvae can be estimated by the equation:

$$Na = \sum_{\ell = 1}^{k} N_\ell \, S_\ell$$

Where:

k = number of larval length classes that are subject to entrainment mortality

N_ℓ = number of length class ℓ killed by entrainment

S_ℓ = Survival probability from length class ℓ to adulthood, which can be derived from the equation:

$$S_\ell = \frac{2}{Se,_\ell \, Fa}$$

Where:

Fa = Average lifetime fecundity

Gizzard shad - 59,480
White perch - 40,000
Sunfishes - 10,751
Black crappie - 37,796
Yellow perch - 23,000

$Se,_\ell$ = survival probability from egg to length class ℓ, which can be derived from the equation:

$$Se,_\ell = He^{-d(L_\ell - h)}$$

Where:

H = fraction of eggs that hatch

L_ℓ = Length of length class ℓ

h = Length at hatching

d = instantaneous mortality rate of length class ℓ, which is derived from the equation:

$$d = -LN \frac{\sum_{\ell = 2}^{k} N_\ell}{\sum_{\ell = 1}^{k} N_\ell}$$

The equivalent adult analysis is based on the following assumptions:

1) There is 100% mortality of entrained larvae

2) The stock populations are at equilibrium and the total lifetime fecundity produces two adults

3) No compensatory mechanisms are operating

4) 75% of the eggs produced by the entrained species survive to the larval stage

Lifetime fecundity values and hatching success rates were averaged from the literature (Schubel 1974; Edsall 1977; New York State Gas and Electric Co. 1977; Hardy 1978; Jones 1978; and Heberling et al. 1981). The hatching success values appear to be high for at least some species. Values for survival of eggs to the larval stage, survival of larvae reaching adult stage and instantaneous rates of mortality were calculated using the above equations.

The results of the analysis (Table 7.2.1) indicate percent cropping, or reduction in adult recruitment caused by entrainment, of each species varied between years and ranged from 0.01% (black crappie in 1978 and 1979; sunfishes in 1982) to 4.13% (gizzard shad in 1980). These percentages reflect differences among years in total estimated standing crop in Lake Anna and the length frequency distribution and total larvae entrained. Generally, yellow perch was relatively most effected by the station's intake during the first 2 years, while during 1981 and 1982 white perch percent cropping was highest. Gizzard shad had the highest percent cropping (4.13%) in 1980. The instantaneous rate of mortality probably was heavily affected in 1980 by the collection of large numbers of length Class 1 larvae, possibly due to a late spawn or a large secondary spawn.

The equivalent adult analysis provided a conservative estimate of entrainment impact because of the assmptions used in the analysis. Larval mortality experienced in entrainment at North Anna is in reality probably less than 100%. The reduction in adult recruitment reported are below values that are thought to cause significant impact on the fishery or the individual populations (Long Island Lighting Co. 1977; New York State and Gas Co. 1977; Heberling et al. 1981; Porak and Tranquilli 1981). No adverse effect due to entrainment on the sport fishery of Lake Sangchris, Illinois was reported by Porak and Tranquilli (1981). Numerical loss of the standing crop at Lake Sangchris was 5.48% for gizzard shad, 15.3% for _Morone_ spp. (White bass and yellow bass) and 0.59% for _Lepomis_ spp. (sunfishes). Regardless of the source of disturbance on fish populations, there is a capacity within populations to offset a reduction in numbers (McFadden 1977). The impact of entrainment at Lake Anna is minimal when values of percent cropping are considered with other population mechanisms, e.g. compensation.

Table 7.2.1 - Results of the Equivalent Adult Analysis of Entrainment Data at North Anna Power Station, 1978-1983.

Species	Year	Number Entrained	Number of Adults (Na)	Total Standing Crop	Percent Cropping
White perch	1978	3.5×10^5	163	7.1×10^5	0.02
Gizzard shad	1978	6.0×10^7	7,797	1.4×10^7	0.06
Black crappie	1978	1.8×10^6	150	1.2×10^6	0.01
Yellow perch	1978	1.3×10^7	24,600	4.4×10^6	0.55
Sunfishes	1978	5.6×10^7	17,677	2.7×10^7	0.07
White perch	1979	6.3×10^6	1,361	8.7×10^5	0.16
Gizzard shad	1979	1.3×10^8	44,336	6.4×10^6	0.69
Black crappie	1979	7.4×10^5	25	2.4×10^6	0.01
Yellow perch	1979	2.0×10^6	8,598	4.7×10^5	1.81
Sunfishes	1979	1.1×10^7	5,061	2.4×10^7	0.02
White perch	1980	1.2×10^7	2,505	1.0×10^6	0.25
Gizzard shad	1980	1.0×10^8	367,787	8.9×10^6	4.13
Black crappie	1980	1.5×10^6	227	2.7×10^5	0.08
Yellow perch	1980	6.0×10^6	741	2.0×10^6	0.04
Sunfishes	1980	2.2×10^7	9,193	4.1×10^7	0.02

Table 7.2.1 (cont'd)

White perch	1981	5.4×10^7	20,736	1.3×10^6	1.70
Gizzard shad	1981	1.6×10^8	17,557	1.2×10^7	0.15
Black crappie	1981	2.6×10^6	323	1.0×10^5	0.31
Yellow perch	1981	1.4×10^7	1,818	1.2×10^6	0.15
Sunfishes	1981	2.1×10^7	14,555	4.2×10^7	0.05
White perch	1982	2.8×10^7	41,380	3.1×10^6	1.3
Gizzard shad	1982	4.0×10^7	3,207	5.3×10^6	0.06
Black crappie	1982	6.6×10^5	329	2.4×10^5	0.14
Yellow perch	1982	3.7×10^6	1,004	1.6×10^6	0.06
Sunfishes	1982	1.2×10^7	3,276	2.7×10^7	0.01
White perch	1983	3.7×10^7	11,636	2.3×10^6	0.52
Gizzard shad	1983	8.9×10^7	56,362	7.8×10^6	0.72
Black crappie	1983	3.2×10^6	3,616	3.1×10^5	1.16
Yellow perch	1983	2.0×10^6	732	6.2×10^5	0.12
Sunfishes	1983	4.0×10^6	17,969	3.5×10^7	0.05

8.0 SUMMARY

Impingement

(1) Impingement studies were conducted at North Anna Power Station from April 1978 through December 1983. A total of 2.4×10^5 fishes weighing 5.7×10^3 kg were collected from the intake screens representing 34 species and 13 families.

(2) The estimated total number of fishes impinged during the over 5-plus-year study period was 9.6×10^5 weighing 2.3×10^4 kg.

(3) Most fish were entrained in 1979 (61%) followed by 1981 (13%), 1980 (12%), 1982 (7%), and 1983 (5%).

(4) Seasonally, the most fish were entrained during the winter (75%) followed by spring (13%), fall (9%), and summer (3%).

(5) A comparison of intake water velocities and fish swimming speeds indicate that a healthy fish larger than 24 mm in total length should be able to avoid the intake current in front of the traveling screens.

(6) The most commonly impinged fish was gizzard shad (65%), followed by black crappie (16%), yellow perch (16%), bluegill (4%) and white perch (1%).

(7) The similarity of impingement length-frequency data and rotenone length frequency data indicate that impingement is a good sampling

device, comparable to rotenone, in determining changes in the population of certain species.

(8) During the 5-plus-year study period, an average 0.32% of the total gizzard shad standing crop (from rotenone data) by weight, or 0.38% , by number, was impinged annually.

(9) One average size 2-year-old female gizzard shad has a fecundity potential greater than the estimated average number of gizzard shad impinged annually.

(10) An average 3.8% of the total black crappie standing crop by weight, or 3.1% by number, was impinged annually.

(11) One average size adult female black crappie theoretically could produce more progeny in 1 year than were impinged.

(12) Forty-five percent more black crappie were estimated to have been creeled in 1984 than were impinged in 1983.

(13) The decline in the black crappie population in Lake Anna does not appear to have been caused by the start-up of the North Anna Power Station.

(14) An average 1.4% of the total yellow perch standing crop by weight, or 0.6% by number, was impinged annually.

(15) Two average size or one large adult female yellow perch could theoretically produce more progeny in 1 year than were impinged.

(16) An average 0.02% of the total bluegill standing crop by weight, or 0.02% by number, was impinged annually.

(17) One average size adult female bluegill theoretically could produce more progeny in 1 year than were impinged.

(18) Almost twice as many bluegill were estimated to have been creeled during 1984 than were estimated to have been impinged during 1983.

(19) An average 0.1% of the total white perch population by weight, or 0.13% by number, were impinged annually.

(20) One average size adult female white perch theoretically could produce more progeny in 1 year than were impinged.

(21) During the 5-plus-year study, an estimated 0.7% of the stocked striped bass were impinged by the power station.

(22) There has been no noticeable adverse impact on the fish stocks of Lake Anna by impingement by the North Anna Nuclear Power Station.

Entrainment

(1) A total of 7,908 fish larvae within five dominant species (gizzard shad, white perch, sunfishes, yellow perch and black crappie) were collected in entrainment samples using stationary conical nets at

North Anna Power Station from 1978-1983. The most abundant entrained larvae over all years were gizzard shad, representing 65.7% of the total. No fish eggs were collected during the sample years.

(2) Over all years and samples the percentage of all fish larvae collected during the midnight sample was 43% of the total caught throughout the day. This was probably due to either the existence of diurnal migration patterns or in part due to net avoidance. Sunfish, on the contrary, were collected more frequently during daylight hours.

(3) The percent of total larvae collected at each sample depth varied from year to year and for each species. Sunfishes, yellow perch and black crappie were collected primarily from surface samples; gizzard shad were collected primarily from middle (4m) and bottom (8m) depths; and white perch numbers were similar at all depths.

(4) The gizzard shad entrainment rate (number per intake pump) declined during the study period while white perch numbers increased.

(5) Total estimated fish larvae entrained ranged from 8.4×10^7 in 1982 to 2.5×10^8 in 1981, represented primarily by gizzard shad.

(6) The results of an equivalent adult model indicated that percent cropping of the Lake Anna fish populations varied between years and each species ranged from 0.01% (black crappie and sunfishes) to 4.13% (gizzard shad). These values are considered below any that may cause significant impact on the Lake Anna fishery.

(7) The impact of entrainment at Lake Anna by the North Anna Power Station on the fish populations is minimal when the reported values of percent cropping are considered with other populations mechanisms such as compensation.

LITERATURE CITED

Aggus, L. R., D. C. Carver, L. L. Olmsted, L. L. Rider and G.L. Summers. 1979. Barkley Lake Symposium: Evaluation of standing crops of fishes in Crooked Creek Bay, Barkley Lake, Kentucky. Proc. Ann. Conf. Assoc. Fish and Wildlife Agencies 33:710-722.

Bainbridge, R. 1958. The speed of swimming fish as related to size and to the frequency of the tail beat. J. Exp. Biol., 35(1):109-33.

Barwick, O. M. 1981. Fecundity of the black crappie in a reservoir receiving heated effluent. Prog. Fish. Cult. 43(3):153-154.

Blaxter, J. H. S. 1969. Swimming speeds of fishes. F.A.D. Fish Rep. 62(2):69-100.

Cada, G. F. and J. M. Loar. 1982. Relative effectiveness of two ichthyoplankton sampling techniques. Canada J. Fish. Aquat. Sci. 39:811-814.

Carlander, K. D. 1969. Handbook of freshwater fishery biology, Vol. I. Iowa State University Press. Amer.

Carter, B. T. 1958. What significant information can be gained from rotenone population studies in impoundments. pp. 82-84, in: Proc. 11th Ann. Conf. S. E. Assoc. Game and Fish Comm. (1957).

Clugston, J. P., J. L. Oliver and R. Ruelle. 1978. Reproduction, growth, and standing crops of yellow perch in Southern Reservoirs. pp. 89-99. in: R. L. Kendall, editor. Selected Coolwater Fishes of North America. Spec. Pub. #11, Amer. Fish. Soc., Washington, D. C.

Cochran, W. G. 1963. Sampling techniques. Wiley and Sons, Inc., New York, New York.

Cooke, A. C. 1984. The expansion of the white perch, Morone americana, population in Lake Anna Reservoir, Virginia. pp. 314-320, in: Lake and Reservoir Management. Proc. of 3rd Annual Conference, North American Lake Management Society. U. S. Environmental Protection Agency, Washington, D. C.

Ecological Analysts, Inc. 1977. A review of entrainment study methodologies: abundance and survival. Prepared for Empire State Electrical Energy Research Corporation, New York, New York.

Eddy, S. and J. C. Underhill. 1943. Northern fishes. University of Minnesota Press., Minneapolis, Minnesota.

Edsall, A. E. 1977. The effect of temperature on the rate of development and survival of alewife eggs and larvae. U. S. Bureau of Commercial Fisheries. Contribution No. 409. Ann Arbor, Michigan.

Edwards, T. J., W. H. Hunt and L. L. Olmsted. 1977. Density and distribution of larval shad (Dorosoma spp.) in Lake Norman, North Carolina - Entrainment at McGuire Nuclear Station. pp. 144-148, in: Proceedings of the first symposium on freshwater larval fish. Edited by L. L. Olmsted, Duke Power Company. Huntersville, North Carolina, USA.

Electric Power Research Institute. 1981. Impingement and entrainment: An updated annotated bibliography. EA-1855. Research Project 877. Ecological Sciences Information Center, Oak Ridge, Tennessee.

Electric Power Research Insitute. 1979. Entrainment: An annotated bibliography. EA-1049. Research Project 877. Ecological Sciences Information Center, Oak Ridge, Tennessee.

Electric Power Research Institute. 1979. Impingement: An annotated bibliography. EA-1050. Research Project 877. Ecological Sciences Information Center, Oak Ridge, Tennessee.

Environmental Protection Agency 1977. Guidance for evaluating the adverse impact of cooling water intake structures on the aquatic environment: Section 316(b) P.L. 92-500. United States Environmental Protection Agency, Washington, D. C.

Environmental Protection Agency 1976. Development document for best technology available for the location, design, construction and capacity of cooling water intake structures for minimizing adverse environmental impact. EPA 440/1-76/015-a. United States Environmental Protection Agency. Washington, D. C.

Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Bd. Canada 15(4):607-624.

Gasser, L. F. 1976. Spatio-temporal distributions of clupeid larvae in Barkley Reservoir. pp. 120-138, in: Proceedings of the Third Symposium on Larval Fish. Edited by R. D. Hoyt. Division of Water Resources, Tennessee Valley Authority. Norris, Tennessee.

Goodyear, P. L. 1978. Entrainment impact estimates using the equivalent adult approach. U. S. Department of Interior, Fish and Wildlife Service. Publication FWS/OBS-78/65. Washington, D. C.

Griffith, J. S. 1978. Effects of low temperature on the survival and behavior of threadfin shad, Dorosoma petenense. Trans. Amer. Fish. Soc. 107(1):63-70.

Hackney, P. A. and J. C. Webb. 1977. A method for determining growth and mortality rates of ichthyoplankton. Division of Forestry, Fisheries and Wildlife Development, Tennessee Valley Authority. Norris, Tennessee.

Hadderingh, R. H. 1982. Experimental reduction of fish impingement by artificial illumination at Bergum Power Station. Int. Rev. Gesamten Hydrobiol. 67(6):869-886.

Hardy, J. D. 1978. Development of fishes of the mid-Atlantic Bight, Volume III. U. S. Department of Interior, Fish and Wildlife Service. Publication FWS/OBS-78/12. Washington, D. C.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. T.F.H. Publications. Neptune, New Jersey.

Hergenrader, G. L. and Q. P. Bliss. 1971. The white perch in Nebraska. Trans. Amer. Fish. Soc. 100:734-738.

Heberling, G. D., K. N. Mueller and J. W. Weinbold. 1981. Section 316(b) Demonstration for the Riverside Generating Plant. Northern States Power Company. Minneapolis, Minnesota.

Horst, T. J. 1975. The assessment of impact due to entrainment of ichthyoplankton. pp. 107-118, in: Symposium on Fisheries and Energy Production. by S. B. Saila. D. C. Heath. Lexington, Massachusetts.

Jenkins, R. M. 1977. Prediction of fish biomass, harvest and prey-predator relations in reservoirs. pp. 282-293, in: W. Van Winkle editor. Proceedings of the conference on assessing the effects of power plant induced mortality on fish populations. Pergamon Press. New York.

Jester, D. B. and B. L. Jensen. 1972. Life history and ecology of gizzard shad, Dorosoma cepedianum (LeSueur) with reference to Elephant Butte Lake, New Mexico State University Agricultural Experiment Station Research Report 218, 56 pp.

Jones, P. W. 1978. Development of fishes of the mid-Atlantic Bight, Volume I. U. S. Department of Interior, Fish and Wildlife Service. Publication FWS/OBS-78/12. Washington, D. C.

Lagler, K. F., J. E. Bardach and B. B. Miller. 1962. Ichthyology. Wiley and Sons. New york, N. Y. pp. 545.

Latvaitus, B. P. 1976. Impingement investigation. pp. 125-168, in: Operation environmental monitoring in the Mississippi River near Quad-Cities Station, February 1975 through January 1976. Nalco Environmental Science, Northbrook, Illinois.

Leithiser, R. M., K. F. Ehrlich, and A. B. Thum. 1979. Comparison of a high volume pump and conventional plankton nets for collecting fish larvae entrained in power plant cooling systems. J. Fish. Res. Board Canada. 36:81-84.

Lippson, A. J. and R. L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River estuary. Martin Marietta Corporation. Baltimore, Maryland. PPSP-MP-13. 282 pp.

Lagler, K. F., J. E. Bardack and R. R. Miller. 1962. Ichthyology. Wiley & Sons. New York, New York. 545 pp.

Long Island Lighting Company. 1977. Environmental statement related to operation of Shoreham Nuclear Power Station Unit 1. U. S. Nuclear Regulatory Commission. Washington, D. C.

Mansueti, R. J. 1964. Eggs, larvae, and young-of-the-year white perch, Reccus americanus, with comments on its ecology in the estuary. Ches. Sci. 5:3-45.

McCauley, R. W. and L. A. A. Read. 1973. Temperature selections by juvenile and adult yellow perch (Perca flavescens) acclimated to 24° C. J. Fish. Res. Bd. Can. 30:1253-1255.

McConnell, G. B. 1975. Fishes section. pp. 80-102, in: Studies on the effects of the Havana Power Station on the ecological balance of the Illinois River 1974 to 1975. Wapora, Inc., Charleston, Ill.

McFadden, J. T. 1977. An argument supporting the reality of compensation in fish populations and a plea to let them exercise it. pp. 153-178, in: Proceedings of the conference on assessing the effects of power-plant-induced mortality on fish populations. Edited by Webster Van Winkle. Pergamon Press. New York.

McLean, R. B., J. J. Beauchamp, V. E. Kane and P. T. Singley. 1982. Impingement of threadfin shad: effects of temperature and hydrography. Environ. Manag. 6(5):431-439.

Netch, N. F., G. M. Kensh, Jr., A. Houser and R. V. Kilambi. 1971. Distribution of young gizzard and threadfin shad in Beaver Reservoir. Reservoir Fisheries and Limnology. Amer. Fish. Soc. Special Publication No. 8, Bethesda, Maryland, USA.

New York State Electric and Gas Corporation. 1977. Report on entrainment at New Haven Nuclear Power Plant. New York State Electric and Gas Corporation. Binghamton, New York.

Ney, J. J. 1978. A synoptic review of yellow perch and walleye biology. pp 1-13. in: R. L. Kendall, editor. Selected Coolwater Fishes of North America. Spec. Pub. #11, Amer. Fish Soc., Washington, D. C.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Dept. of Conservation. 343 pp.

Polgar, T. T. 1977. Striped bass ichthyoplankton abundance, mortality and production estimation for the Potomac River population. pp. 110-126, in: Proceedings of the conference on assessing the effects of power-plant-induced mortality on fish populations held in Gatlinburg, Tennessee. Pergammon Press, New York, New York.

Porak, W. and J. A. Tranquilli. 1981. Impingement and entrainment of fishes at Kincaid Generating Station. Illinois Nat. Hist. Survey Bull. 32(4):631-655.

Reid, G. K. and R. D. Wood. 1976. Ecology of inland waters and estuaries. D. Van Nostrand Co. New York, New York.

Reutter, J. M. and C. E. Herdendorf. 1979. Impingement and entrainment at the Davis-Besse Nuclear Power Station Unit I, 316(b) demonstration. Ohio State University. Center for Lake Erie area research. Columbus, Ohio.

Ricker, W. E. 1954. Stock and recruitment. Journal Fish. Res. Board Can. 11:559-623.

Schneeberger, P. J. and D. J. Jude. 1981. Use of fish larva morphometry to predict exclusion capabilities of small-mesh screens at cooling-water intakes. Trans. Amer. Fish. Society. 110:246-252.

Schubel, J. R. 1974. Effects of exposure to time - excess temperature histories typically experienced at power plants on the hatching success of fish eggs. Prepared for the Power Plant Siting Program. Maryland Department of Natural Resources. Baltimore, Maryland.

Scotton, L. N. and D. T. Anson, II. 1977. Protecting aquatic life at plant intakes. Power 121(1): 74-76.

Sledd, C. A. and D. J. Shuber. 1981. Project completion report for Virginia. Dingell-Johnson project F-33-R. Virginia Commission of Game and Inland Fisheries. Richmond, Virginia.

St. Pierre, R. A. and J. Davis. 1972. Age, growth, and mortality of the white perch Morone americana, in the James and York Rivers, Virginia. Ches. Sci. 13(4):272-281.

Swedberg, D. V. and C. H. Wallburg. 1970. Spawning and early life history of the freshwater drum in Lewis and Clark Lake, Missouri River. in: Trans. Amer. Fish. Soc. Publication No. 90:560-570. Bethesda, Maryland.

Swingle, H. S. and W. E. Swingle. 1968. Problems in dynamics of fish populations in reservoirs. pp. 229-243, in: Amer. Fish. Soc. Res. Fish Resource Symp. Athens, Georgia.

Tuberville, J. D. 1977. Vertical distribution of ichthyoplankton in upper Nickajack Reservoir. Fisheries Resources Branch, Division of Water Resources, Tennessee Valley Authority. Norris, Tennessee, USA.

Virginia Department of Conservation and Economic Development/Division of Water Resources. 1970. York River Basin - Comprehensive Water Resources Plan. Volume III. Richmond, Virginia.

Virginia Electric and Power Company. 1984. Environmental study of Lake Anna and the lower North Anna River: Summary report 1983. Richmond, Virginia.

Virginia Electric and Power Company. 1983. Environmental study of Lake Anna and the lower North Anna River: North Anna Power Station annual report, January 1-December 31, 1982. Richmond, Virginia.

Wallace, D. C. 1971. Age, growth, year-class strength, and survival rates of the white perch, Morone americana (Gmelin) in the Delaware River in the vicinity of Artificial Island. Ches. Sci. 12:205-218.

White, J. W. and M. L. Brehmer. 1976. Third national workshop on entrainment and impingement, Section 316(b)-Research and compliance, held in New York, New York. Ecological Analysts, Inc., Melville, New York. pp. 367-380.

Zeitoun, I. H. and J. A. Gulvas. 1981. Effectiveness of fine mesh cylindrical wedge - wire screens in reducing entrainment of Lake Michigan ichthyoplankton Canada J. Fish. Aquat. Sci. 38:120-125.

Zeitoun, I. H. and J. A. Gulvas. 1980. Power plant water intake assessment. Amer. Chem. Soc. 14(4):398-402.

APPENDIX A.

SUMMARY OF NORTH ANNA ENVIRONMENTAL REPORTS
LISTED BY DATE SUBMITTED

NORTH ANNA RIVER, VIRGINIA.
BY ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA
FOR NEW JERSEY ZINC COMPANY
*****DATE SUBMITTED - 1955*****

COMMUNITY STRUCTURE OF THE MACROBENTHOS IN FOUR TRIBUTARIES IN THE PRE-IMPOUNDMENT BASIS OF THE NORTH ANNA RIVER, VIRGINIA.
BY M.H. THOMAS AND G.M. SIMMONS
ASSOC. SOUTHEAST BIOL., BULL., 17(2) (ABSTRACT)
*****DATE SUBMITTED - 1967*****

A PRE-IMPOUNDMENT ECOLOGICAL STUDY OF THE BENTHIC FAUNA AND WATER QUALITY IN THE NORTH ANNA RIVER, 1969-1970.
BY G.M. SIMMONS, JR. PROJECT A-031-VA.(DEPT BIOLOGY, VCU)
OFFICE OF WATER RESOURCES RESEARCH, U.S.D.I.
*****DATE SUBMITTED - 1970*****

YORK RIVER BASIN VOLUME III-HYDROLOGIC ANALYSIS.
BY VIRGINIA DEPT. CONSERVATION AND ECONOMIC DEVELOPMENT.
PLANNING BULLETIN 227
*****DATE SUBMITTED - 1970*****

AN ECOLOGICAL INVESTIGATION OF THE LOWER NORTH ANNA AND UPPER PAMUNKEY RIVER SYSTEM - 1971
BY JAMES R. REED, JR., PH.D. VCU DEPT. BIO. AND
GEORGE M. SIMMONS, JR., PH.D. VPI & SU DEPT. BIO.
FOR MR. J.D. RISTROPH, EXEC. DIR., VEPCO
ONE VOLUME (110P) - PHYSICAL/CHEMICAL (TEMPERATURE,TOTAL SOLIDS, TURBIDITY,OXYGEN,PH,CONDUCTIVITY,SALINITY,NUTRIENTS - PO4_P,NO3_N,SO4) BENTHICS, FISHES
*****DATE SUBMITTED - JANUARY 18, 1972*****

FINAL ENVIRONMENTAL STATEMENT RELATED TO THE CONTINUATION OF CONSTRUCTION AND THE OPERATION OF UNITS 1 & 2 AND THE CONSTRUCTION OF UNITS 3 & 4, NORTH ANNA POWER STATION.
BY VEPCO FOR THE US. ATOMIC ENERGY COMMISSION
ONE VOLUME - IMPACT STUDY OF THE PROPOSED STATION ON THE ENVIRONS OF THE LAKE AND THE STATION.
*****DATE SUBMITTED - 1973*****

DISTRIBUTION OF HEAVY METALS IN LAKE ANNA, A SYSTEM AFFECTED BY ACID MINE DRAINAGE.
BY ELIZABETH R. BLOOD M.S. THESES FOR VCU
*****DATE SUBMITTED - 1975*****

WATER QUALITY INVENTORY (305(B) REPORT) : VIRGINIA. REPORT TO EPA ADMINISTRATION AND CONGRESS.
BY VIRGINIA STATE WATER CONTROL BOARD INFO. BULL. 526
*****DATE SUBMITTED - 1976*****

APPENDIX A.(cont'd)

PRE-OPERATIONAL ENVIRONMENTAL STUDY OF LAKE ANNA, VIRGINIA (FINAL REPORT) - MARCH 1972 - DECEMBER 1975
BY JAMES R. REED, JR., PH.D. VCU DEPT. BIO. AND
GEORGE M. SIMMONS, JR., PH.D. VPI & SU DEPT. BIO.
FOR VEPCO
VOLUME 1 - NARRATIVE - INTRO,METHODS,RESULTS (666P)
HEAVY METALS (WATER,FISH,SEDIMENT,MACROPHYTES,BENTHICS, SESTON,RIVER), PHYTOPLANKTON,CHLOROPHYLL,PRODUCTIVITY, ZOOPLANKTON, BENTHICS (LAKE & RIVER), ICHTHYOLOGY (WATER QUALITY,FOOD HABITS,POPULATIONS,AGE & GROWTH-LMB FECUNDITY,GONAD CYCLES,OVUM MATURITY,RIVER), STATISTICAL ANALYSES
VOLUME 2 - DATA BASE - PHYSICAL & CHEMICAL,NUTRIENTS,METALS <456P)
VOLUME 3(1) - DATA BASE - PHYTOPLANKTON DENSITY, VOLUME (517P)
VOLUME 3(2) - DATA BASE - PHYTOPLANKTON %COMPOSITION,CHLOROPHYLL, ORGANIC ASSIMILATION RATES (372P)
VOLUME 4 - DATA BASE - ZOOPLANKTON (317P)
VOLUME 5 & 6 - DATA BASE - MACROINVERTEBRATES (140P), FISHES (80P)
*****DATE SUBMITTED - SEPTEMBER 1976*****

PRE-OPERATIONAL ENVIRONMENTAL STUDY OF LAKE ANNA, VIRGINIA (ANNUAL REPORT) - 1976
BY GEORGE M. SIMMONS, JR., PH.D. VPI & SU DEPT. BIO.
FOR VEPCO
ONE VOLUME (546P) - PHYSIOCHEMICAL (TEMPERATURE,SPECIFIC CONDUCTANCE,SECCHI,OXYGEN,ALKALINITY,PH,NUTRIENTS - PO4_P,NH3_N,NO3_N,SO4,SILICATES),RIVER STUDY, PHYTOPLANKTON,PRODUCTIVITY,CHLOROPHYLL,MACROPHYTES, ZOOPLANKTON, BENTHICS (LAKE,RIVER,SAMPLER COMPARISON)
*****DATE SUBMITTED - MARCH 30, 1977*****

(PRE-OP) ENVIRONMENTAL STUDY OF LAKE ANNA, VIRGINIA (ANNUAL REPORT) - JANUARY 1,1976 - DECEMBER 31,1976
BY JAMES R. REED AND ASSOC., NEWPORT NEWS,VA.
FOR VEPCO
ONE VOLUME (109P) - FISH,WATER QUALITY,POPULATIONS,LMB AGE & GROWTH,FECUNDITY,GONAD DEVELOPMENT,OVUM MATURITY,RIVER STUDIES,STATISTICAL ANAYLSES), HEAVY METALS (WATER, SEDIMENT,FISH TISSUE,RIVER STUDIES)
*****DATE SUBMITTED - MARCH 1977*****

PRE-OPERATIONAL ENVIRONMENTAL STUDY OF LAKE ANNA, VIRGINIA (ANNUAL REPORT) - 1977
BY GEORGE M. SIMMONS, JR., PH.D. VPI & SU DEPT. BIO.
FOR VEPCO
ONE VOLUME (588P) - PHYSIOCHEMICAL (TEMPERATURE,SPECIFIC CONDUCTANCE,SECCHI,OXYGEN,ALKALINITY,PH,NUTRIENTS - PO4_P,NH3_N,NO3_N,SO4,SILICATES),RIVER STUDY, PHYTOPLANKTON,PRODUCTIVITY,CHLOROPHYLL,ZOOPLANKTON, BENTHICS (LAKE,RIVER)
*****DATE SUBMITTED - MARCH 15, 1978*****

(PRE-OP) ENVIRONMENTAL STUDY OF LAKE ANNA, VIRGINIA (ANNUAL REPORT) - JANUARY 1,1977 - DECEMBER 31,1977
BY JAMES R. REED AND ASSOC., NEWPORT NEWS,VA.
FOR VEPCO
VOLUME 1 - ICHTHYOLOGY, METALS - METHODS,MATERIALS,RESULTS (142P)
VOLUME 2 - DATA BASE (85P)
*****DATE SUBMITTED - FEBRUARY 28, 1978*****

ENVIRONMENTAL STUDY OF LAKE ANNA, VIRGINIA (ANNUAL REPORT) -
JANUARY 1,1978 - DECEMBER 31,1978
BY JAMES R. REED AND ASSOC., NEWPORT NEWS,VA.
FOR VEPCO
VOLUME 1 - DATA BASE - METALS,NUTRIENTS,PRODUCTIVITY,CHLOROPHYLL, WATER QUALITY,PHYTOPLANKTON (221P)
VOLUME 2 - DATA BASE - PHYTOPLANKTON, ZOOPLANKTON (219P)
VOLUME 3 - DATA BASE - ZOOPLANKTON,BENTHICS,FISH (220P)
VOLUME 4 - NARRATIVE - SUMMARY,INTRO,METHODS,RESULTS (186P) HEAVY METALS, NUTRIENTS (NO3_N,NH3_N,PO4_P,SO4) PRODUCTIVITY,CHLOROPHYLL,PHYSICAL & CHEMICAL, PHYTOPLANKTON,ZOOPLANKTON,MACROBENTHOS,FISHERIES, (WATER QUALITY,POPULATIONS,AGE & GROWTH - LMB, FECUNDITY,GONAD DEVELOPMENT)
VOLUME 5 - DOWNSTREAM - SUMMARY,METHODS,MATERIALS,RESULTS (81P) DATA BASE,PHYSICAL & CHEMICAL,FISH,MACROBENTHOS
*****DATE SUBMITTED - MARCH 31, 1979*****

NORTH ANNA POWER STATION (NAPS) NON-RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT - 1978
BY VEPCO
ONE VOLUME - THERMAL MEASUREMENTS (SYNOPTIC SURVEYS),IMPINGEMENT, ENTRAINMENT,WATER QUALITY & ECOLOGICAL SURVEY (REED, 1978 - NARRATIVE,186P),TRANSMISSION LINE ROW,ONSITE METEORLOGICAL MONITORING,CHEMICAL INVENTORY,NON-RAD LIMITING CONDITIONS,VEGETATION STUDIES
*****DATE SUBMITTED - APRIL. 1979*****

ENVIRONMENTAL STUDY OF LAKE ANNA, VIRGINIA (ANNUAL REPORT) -
JANUARY 1,1979 - DECEMBER 31,1979
BY JAMES R. REED AND ASSOC., NEWPORT NEWS,VA.
FOR VEPCO
VOLUME 1 - DATA BASE - NUTRIENTS,METALS,CHLOROPHYLL,PRODUCTIVITY, PHYTOPLANKTON,ZOOPLANKTON (174P)
VOLUME 2 - DATA BASE - ZOOPLANKTON,MACROBENTHOS (270P)
VOLUME 3 - DATA BASE - FISH STUDIES (PHYSICAL & CHEMICAL,SPECIES LIST) (398P)
VOLUME 4 - NARRATIVE - INTRO,SUMMARY,METHODS,RESULTS (175P) HEAVY METALS,NUTRIENTS (NO3_N,NH3_N,PO4_P,SO4) CHLOROPHYLL,PRODUCTIVITY,TEMPERATURE,PHYTOPLANKTON, ZOOPLANKTON,MACROBENTHOS,FISH (WATER QUALITY, POPULATIONS,AGE & GROWTH - LMB)
VOLUME 5 - DOWNSTREAM - INTRO,METHODS,RESULTS (69P) DATA BASE, PHYSICAL & CHEMICAL,FISH (ENDEMIC/ENDANGERED SPP,SMALLMOUTH BASS), MACROBENTHOS
*****DATE SUBMITTED - MARCH 31, 1980*****

NORTH ANNA POWER STATION (NAPS) NON-RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT, UNITS 1 & 2 - 1980
BY VEPCO
VOLUME 1 - THERMAL, IMPINGEMENT, ENTRAINMENT
VOLUME 2 - WATER QUALITY & ECOLOGICAL SURVEY (REED, 1981)
*****DATE SUBMITTED - APRIL 8, 1981*****

APPENDIX A. (cont'd)

ENVIRONMENTAL STUDY OF LAKE ANNA, VIRGINIA (ANNUAL REPORT) -
JANUARY 1,1980 - DECEMBER 31,1980
BY JAMES R. REED AND ASSOC., NEWPORT NEWS,VA.
FOR VEPCO
VOLUME 1 - DATA BASE - NUTRIENTS,METALS,CHLOROPHYLL,PRODUCTIVITY, PHYSICAL,CHEMICAL,CLIMATE,PHYTOPLANKTON (235P)
VOLUME 2 - DATA BASE - PHYTOPLANKTON,ZOOPLANKTON(189P)
VOLUME 3 - DATA BASE - ZOOPLANKTON,MACROBENTHOS,FISH(PHYSICAL & CHEMICAL,SPECIES LIST,GILL NET,ROTENONE,AGE & GROWTH - LMB) (133P)
VOLUME 4 - NARRATIVE - INTRO,SUMMARY,METHODS,RESULTS (154P) HEAVY METALS,NUTRIENTS(NO3_N,NH3_N,PO4_P,SO4) CHLOROPHYLL,PRODUCTIVITY,TEMPERATURE,PHYTOPLANKTON, ZOOPLANKTON,MACROBENTHOS,FISH(WATER QUALITY,POPULATIONS AGE & GROWTH - LMB)
VOLUME 5 - DOWNSTREAM - SUMMARY,INTRO,METHODS,RESULTS (83P) DATA BASE - PHYSICAL & CHEMICAL,FISH,MACROBENTHOS
*****DATE SUBMITTED - MAY 1, 1981*****

LAKE ANNA RESEARCH STUDY (PROJECT COMPLETION REPORT) -
JANUARY 1, 1976 - DECEMBER 31,1980
BY CHARLES A. SLEDD AND DANIEL J. SHUBER, VIRGINIA COMMISSION OF GAME AND INLAND FISHERIES, RICHMOND, VIRGINIA
ONE VOLUME (67P) - SPORT FISHERY CREEL SURVEY, LIMNOLOGICAL INVESTIGATION (WATER TEMPERATURE,DISSOLVED OXYGEN, HEAVY METALS,PLANKTON), FISH POPULATION STUDIES (STANDING CROP,GILL NETTING,AGE & GROWTH,LENGTH WEIGHT RELATIONSHIP & INDEX OF CONDITION,NORTH ANNA RIVER)
*****DATE SUBMITTED - OCTOBER, 1981*****

RECLAMATION OF TOXIC MINE WASTE UTILIZING SEWAGE SLUDGE -CONTRARY CREEK DEMONSTRATION, PROJECT SUMMARY.
BY KENNETH HINKLE EPA-600/S2-82-061
*****DATE SUBMITTED - 1982*****

UPDATED FINAL SAFETY ANALYSIS REPORT, NORTH ANNA NUCLEAR POWER STATION
BY VEPCO, DIRECTOR OF SAFETY, EVALUATION AND CONTROL.
16 VOLUMES
*****DATE SUBMITTED - 1982*****

NORTH ANNA POWER STATION (NAPS) NON-RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT, UNITS 1 & 2 - 1981
BY VEPCO
ONE VOLUME, INCLUDES VEGETATION STUDY (SCANLAN,1982)
*****DATE SUBMITTED - MARCH 30, 1982*****

ENVIRONMENTAL STUDY OF LAKE ANNA, VIRGINIA (ANNUAL REPORT) -
JANUARY 1 - DECEMBER 31, 1981
BY VEPCO
VOLUME 1 - STATION OPERATION, PHYSICAL & CHEMICAL, ZOOPLANKTON, BENTHICS,ENTRAINMENT (275P)
VOLUME 2 - ICHTHYOPLANKTON,IMPINGEMENT,FISH,WATERFOWL (297P)
VOLUME 3 - DOWNSTREAM (113P)
*****DATE SUBMITTED - APRIL, 1982*****

APPENDIX A. (cont'd)

ENVIRONMENTAL STUDY OF LAKE ANNA & THE LOWER NORTH ANNA RIVER (ANNUAL REPORT) - JANUARY 1,1982 - DECEMBER 31,1982
BY VEPCO
VOLUME 1 - STATION OPERATION, PHYSICAL & CHEMICAL,ZOOPLANKTON, BENTHICS,ENTRAINMENT,ICHTHYOPLANKTON,IMPINGEMENT (331P)
VOLUME 2 - FISHES,MACROPHYTES,WATERFOWL,NORTH ANNA RIVER (349P)
*****DATE SUBMITTED - AUGUST, 1983*****

EXPANSION OF THE WHITE PERCH (MORONE AMERICANA) IN LAKE ANNA, VIRGINIA.
BY ARTHUR C. COOKE PRESENTED AT THE 1983 SYMPOSIUM OF THE NORTH AMERICAN LAKE MANAGEMENT SOCIETY, PUBLISHED IN THE 1984 PROCEEDINGS
*****DATE SUBMITTED - AUGUST 1983*****

ENVIRONMENTAL STUDY OF LAKE ANNA AND THE LOWER NORTH ANNA RIVER-SUMMARY REPORT - JANUARY 1, 1983 - DECEMBER 31, 1983
BY VEPCO
ONE VOLUME - SUMMARY, STATION OPERATION, WATER QUALITY, ZOOPLANKTON, BENTHOS, ICHTHYOPLANKTON, FISHES
*****DATE SUBMITTED - JULY 1984*****

316(A) DEMONSTRATION; PROGRESS REPORT, JANUARY - JUNE 1984, LAKE ANNA AND THE LOWER NORTH ANNA RIVER
BY VEPCO
ONE VOLUME - STATION OPERATION, THERMAL PLUME SURVEYS, FIXED TEMPERATURE RECORDERS, WATER QUALITY, PHYTOPLANKTON, PERIPHYTON, ZOOPLANKTON, BENTHIC MACROINVERTEBRATES, ICHTHYOPLANKTON, FISHES(STRIPED BASS SONIC TAGGING, SMALLMOUTH BASS SURVEYS) MACROPHYTES, WATERFOWL
*****DATE SUBMITTED - AUGUST 1984*****

WATER QUALITY CHARACTERISTICS OF A THERMALLY-INFLUENCED RESERVOIR, LAKE ANNA, VIRGINIA RELATED TO EURYTHERMIC AND MESOTHERMIC SPECIES PREFERENDA.
BY JOYCE L. BARTON PRESENTED AT THE 1984 SYMPOSIUM OF THE NORTH AMERICAN LAKE MANAGEMENT SOCIETY, SUBMITTED FOR THE PROCEEDINGS TO BE PUBLISHED IN 1985
*****DATE SUBMITTED - AUGUST 1984*****

APPENDIX B. Technical Specifications for Station Components.

Main Condensers

Mfr. Ingersoll-Rand Company

Active tube surface, %	100
Circulating water, gpm	940,300
Steam condensed, Mlb/hr	7,096
Heat transfer steam condensed, Btu/lb	915.5
Tube water velocity, ft/sec	8.0
Circulating water temperature (in), F	93
Circulating water temperature (out), F	107.1
Temperature condenser from hot well, F	119.5
Absolute pressure main steam inlet, in. Hg	3.41
Surface area, sq ft	618,000
No. of shells	2
Passes per shell	1
Total number of tubes	53,856
Tube outer diameter, in.	1.0
Tube length, ft-in.	44-0
Test pressure, psig	25
Material	
Shell	A285, Gr. C
Tubes	304 SS
Tube sheets	Solid 304 SS
Hot well	A285, Gr. C
Baffles	A285, Gr. C
Reference drawing	FM-17A, FC-4
Location	Turbine bldg.

APPENDIX B. - (cont'd)

Circulating Water Traveling Screens

Mfr. Rex Chainbelt, Inc.

With water surface at average level	
Elevation of surface, ft-in.	250
Screen capacity, gpm	230,000
Submergence, ft-in.	29-0
Well width, ft-in.	14-3 1/2
Depth below operating floor, ft-in.	44-0
Overall screen height, ft-in.	54-0
Centers, headshaft to foot shaft, ft-in.	45-0
Screen travel speed, fpm (high speed)	10
Time for one complete revolution, min.	10.2
Flow of spray water per screen, gpm	380
Pressure of spray water per screen, psig	80

Element	Size	Material
Head shaft	5 15/16" diam.	AISI C 1018
Foot shaft	2 7/16" diam.	AISI C 1018
Screen guides	4/5 ft long	ASTM A48-48C1-20
Spray nozzles	Orifice size 22	Cast Alum., bronze
Spray headers	5" pipe size	Steel
Screen panels	24" x 14'-0"	Carbon steel
Splash plates	3/16"	Molded fiberglass
Drive Mechanism		
Housing	1/4" plate	Carbon steel
Head sprocket	48" pitch diam.	ASTM A 148-58-80-40
Foot wheel	48" pitch diam.	ASTM A 48-48 C1.30

Weight of heaviest section to lift during erection, lb	16,200
Reference drawing	FM-21A
Location	Screenwell

APPENDIX B. - (cont'd)

Circulating Water Pump

Mfr. Ingersoll-Rand Company	
Pump design	
Flow, gpm	238,200
Head, ft	25
Temperature, F	40-93
Efficiency, %	85
NPSH (available/required), ft	50.5/37
Bhp (normal/maximum)	1,769/2,650
Speed, rpm	250
Type	Vertical centrifugal
Casing design	45
Design pressure, psig	
Design temperature, F	
Material	A48 cast iron
Motor	
Horsepower	2,000
Voltage	4,000
Speed, rpm	257
Insulation	Class B
Type	Squirrel cage
Weight (pump & base), lb.	100,000
Reference drawing	FM-34A, FM-21A
Location	Screenwell

APPENDIX B. - (cont'd)

Screenwash Pumps

Mfr. Johnston Pump Company

Pump design	
Flow, gpm	910
Heat, ft	225
Temperature, F	40-93
Efficiency, %	83
NPSH (available/required), ft	/14
Bhp (normal/maximum)	61.7/64
Speed, rpm	1,760
Type	Vertical turbine
Casing design	
Design pressure, psig	175
Material	Cast Iron
Motor	
Horsepower	75
Voltage	460
Speed, rpm	1,760
Insulation	Class B
Type	Squirrel cage
Weight (pump & base), lb	2,400
Reference drawing	FM-34A, FM-21A
Location	Screenwell